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Smithsonian·July 1995

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Cover:
In a computer-manipulated image, B-52s await Russian verification of their destruction. Photograph by Chad Slattery.

Departments

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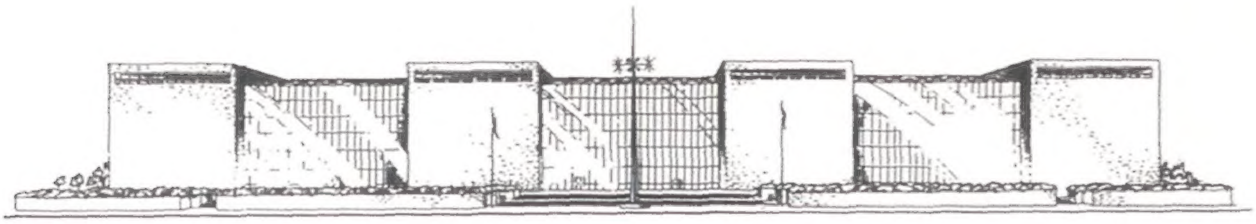

Tower of Babel

International aerospace ventures are in vogue these days and can save a great deal of money. But there are two different approaches.

The aircraft industry has chosen one tack. Parts of a Boeing 747 are built all over the world, shipped to Seattle, and then assembled into the final product. Shopping internationally provides the best price on each item. And if a supplier doesn't reliably deliver, a competitor in some other country is ready to step in. Private industry has the flexibility to effect such substitutions.

Markedly different is the governmental approach of building the space station. Here, long-term cooperation is worked out in treaties that outlast swings in the economies of participating nations and the attention spans of their legislatures. Moreover, political factors are also important.

The question is: Are such collaborative agreements wise and do they save money in the long run?

Collaboration on the space station with Russia is one problem. The transition from a Soviet Union to a loose aggregate of ethnically divergent nations has been difficult. The former Soviet Union's production capabilities are largely in Russia, while the launch complexes are in Kazakhstan. And the changes from a centrally controlled economy to a free market one are still fraught with logistical problems. Is that the partner we should seek for constructing an ambitious and costly space station?

The answer may have to be a resigned "yes." We worry that many of the former Soviet Union's crack scientists and engineers could go to work for Third World countries that want to construct nuclear missiles. By providing Russian technical experts both salaries and interesting work, the logic goes, we may be able to keep them from leaving and save ourselves from far greater headaches a decade hence. Besides, when orginally approved, the project was hailed as a wonderful way to use deadly missiles to truck equipment to the space station.

The partnership with Western Europe is also troubled. The European Space Agency (ESA), emboldened by the success of its Ariane IV in snaring a major share of commercial launches worldwide, is now about to introduce its heavy-lift launcher Ariane V. While cost-cutting pressures led ESA to scrap the Crew Rescue Vehicle, the Europeans would like to see the Ariane V used in building the space station—thus competing with NASA's space shuttle.

This is part of ESA's march toward greater self-reliance and independence from NASA, whose annual budget battles and occasional defeats in Congress have expensive consequences for Europe. ESA's more steadfast support from its member states permits pursuit of long-range plans and avoids costly design changes.

Given these political differences, how can international approaches even hope to succeed?

One course would be for different countries to build smaller, complementing, but separately viable units, building blocks of an overarching space program to which all agreed and in which all had rights and privileges. This could mean dividing a major project like the space station into parts, each essential in its own right but all able to be mated into a larger whole. Procurement of parts and services should be competitive, as in the aircraft industry, without the encumbrances of political considerations.

When politically motivated support is necessary, as it is for Russia, it should be disentangled from such complex technical projects whenever possible.

No major space program can be expected to succeed when critical decisions have to be reached in three or more independently operating countries, each with its own political pressures.

Internationalism can be beneficial to all. But it should avoid costly, non-essential interdependencies.

—Martin Harwit resigned as director of the National Air and Space Museum on May 2.

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LETTERS

The Cold, Hard Facts

I have listened to countless military aviators talk about how they planned to "get out" and pursue the life of a bush pilot, but few would ever give up the comforts of their job to live like bandits on the ragged edge of civilization. I will recommend they all read "The Magnetic North" (Apr./May 1995), with its outstanding insights into the often overglorified life of a bush pilot.

—Eric J. Stierna
Enterprise, Alabama

A Cadet Never Forgets

From 1950 to 1954, I was a graduate student in the department of bacteriology and immunology at the University of Minnesota. To fulfill our research requirements, we worked on weekends, and while we did our experiments we would listen to the radio. Among our favorite programs was "Tom Corbett, Space Cadet" (Apr./May 1995).

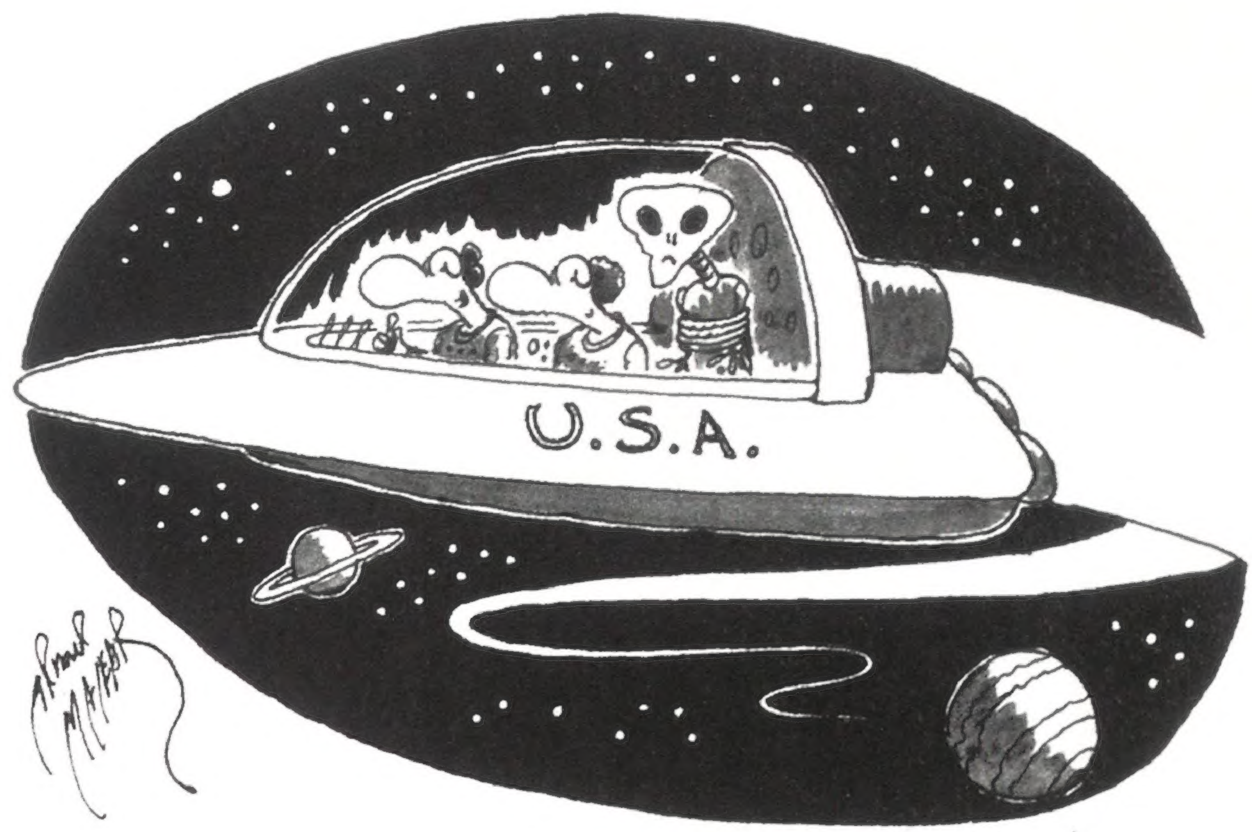
Since then, I have been to a lot of places and done a lot of things. I have learned a lot and forgotten a lot. However, after 40-plus years, still fresh in my mind is the phrase "Smoking rockets, Captain!"—another classic of the Corbett lexicon.

—William L. Boyd
Fort Collins, Colorado

Nothing New Under the Sun

The article "Disk Drive" (Soundings, Feb./Mar. 1995), which describes the flying saucer developed by George Neumayr, states: "Now, for the first time in 60 years, the U.S. government has granted a patent for a new flying machine." Actually, when I worked in the U.S. Patent Office as an examiner some years ago, I discovered that an astounding variety of flying saucers have been patented, not just by individuals but also by well-known aeronautical companies.

—Jan P. Koniarek
Briarcliff Manor, New York



"It's payback time!"

The Price Is Wrong

I thoroughly disagree with Alex Roland's "The Price of Peace" (Apr./May 1995). First, to say that "we did not have the greatest stake in the outcome [of the Gulf war]" is totally blind. Given how much our nation depends on the Gulf region for oil, Iraq's overrunning other Gulf nations would have been catastrophic to the independence of all Americans.

Second, I almost fell off my chair when I read Mr. Roland's suggestion that "the United States could encourage other countries to lower their military spending by promising to lower ours proportionally." If Mr. Roland were an international arms limitation negotiator, I suppose he would say: "Well, we'll be nice guys if you'll be nice guys, okay?" How would we track another nation's military expenditures, and how would other nations track ours? Ours are none of their business, to put it bluntly.

As to Mr. Roland's suggestion that we impose sanctions on any nation spending disproportionally on military force, I believe those are an empty threat. If all the United States had done to the Axis powers during World War II was impose sanctions, the outcome would have been disastrous.

—Peter J. Grabowsky
Blairstown, New Jersey

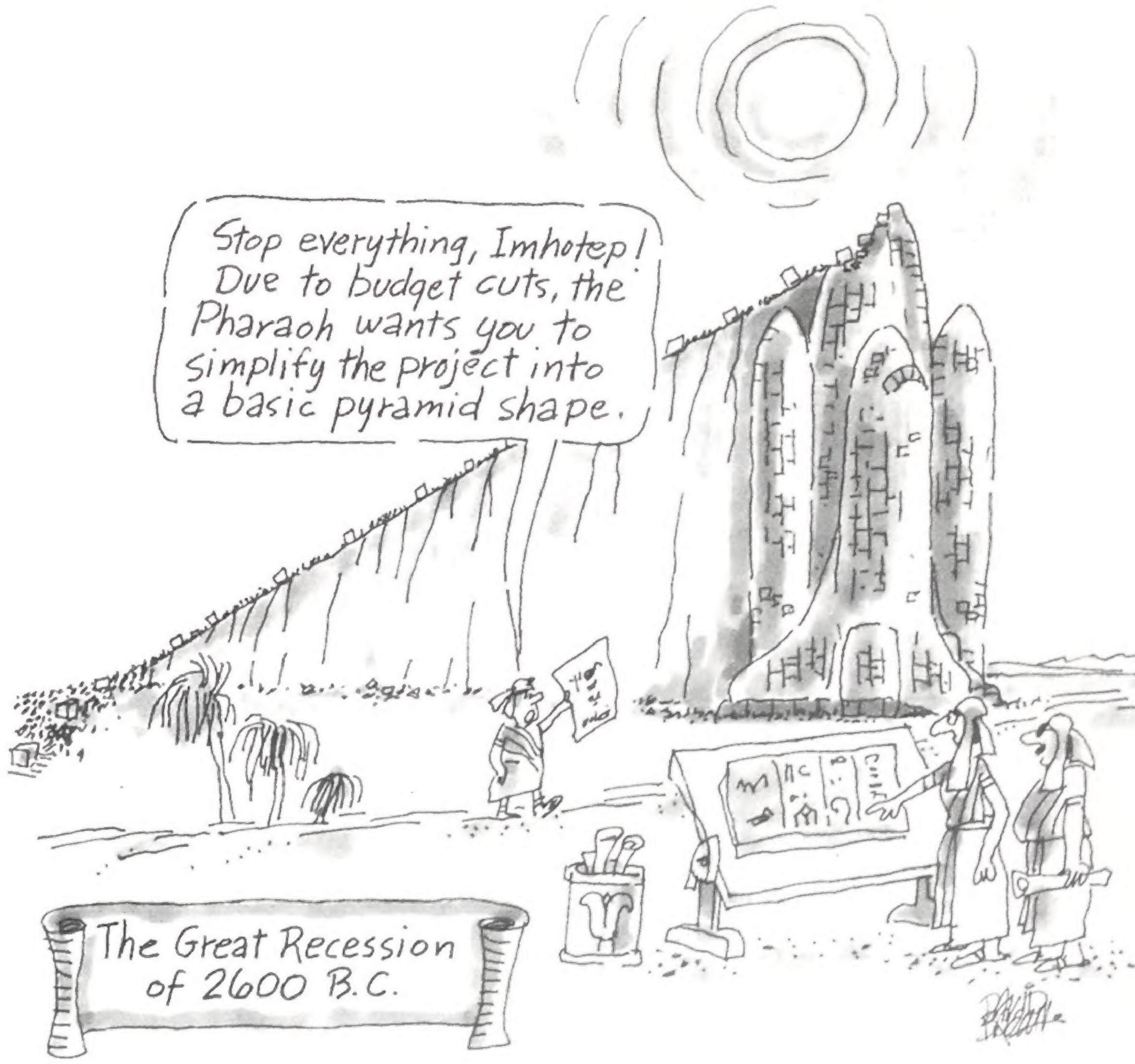
Alex Roland replies: Mr. Grabowsky peers out from fortress America and sees a dangerous world. Most of the danger, however, is in his mind. Kuwait and Saudi Arabia had far higher stakes in the Gulf war than did the United States. U.S. and world military expenditures are everyone's business. Heaven knows what nations Mr. Grabowsky equates with the Axis powers of World War II. My essay actually recommended an increase in U.S. defense spending, but I suspect that no increase will ever be enough to quiet Mr. Grabowsky's fears.

Damage Control

"After the Dust Settles" (Soundings, Apr./May 1995) included a puzzling picture of the X-31 crash site. Though the fire damage is clear, can you explain why the aircraft's leading edges—tail, wings, nose, even speed indicator probe—appear undamaged?

—Jonas Kova
Rocky Hill, Connecticut

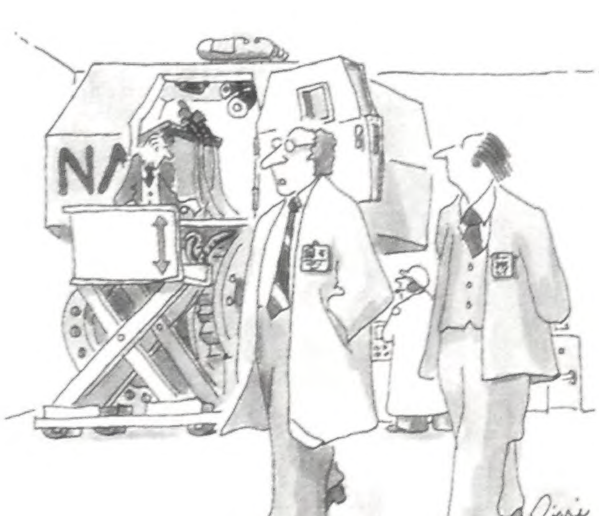
Stephan Wilkinson replies: Having just rolled upright from what seemed to be an inverted spin, the X-31 hit the ground tail first and in a left-wing-down attitude, with almost no forward speed but a very high rate of sink.



The Lighter Side of Gravity

Reading "Heavens on Earth" (Feb./Mar. 1995) reminded me of my own discovery of the zero-G parabolic arc now flown by NASA's "Vomit Comet." One day in 1945, while flying a North American Harvard for the Royal Canadian Air Force, I noticed that as I was easing over into a dive earthward, something was floating up in front of my face. It was the intercom/radio microphone, which had come loose. I experimented with delicate fore and aft adjustments of the joy stick to see if I could hold the microphone directly in front of my face. Of course, I couldn't keep that up very long because soon we were pointing straight down.

—Allan L. Phillips
Westland, Michigan



"And that's our press conference simulator."

Reappraising Goldin

In "Mr. Goldin Goes to Washington" (Apr./May 1995), Dan Goldin talks of our finding a life-bearing planet within 10 light-years of Earth, and reaching it in 50 to 100 years. According to my calculations, flying a 10-light-year distance in 100 years would require us to travel 67 *million* mph. Even if we could attain that speed and maintain it, how would we crew such a craft over the course of a century? Multiple generations? Can we conceive offspring, and could they develop, in outer space?

We don't need to look for life-bearing planets around other solar systems; we can create them right in our own solar system, by establishing colonies on the moon and Mars and terraforming these bodies' surfaces and atmospheres. And with current propulsion technologies, we can reach these outposts in months or weeks, rather than decades.

—Tony Peña
San Jose, California

Your Dan Goldin profile portrays an aspect of the NASA administrator that has been lacking since the days of James Webb and the Apollo program. A large portion of the American public is all but illiterate in science and engineering, and as the peripatetic ambassador for NASA, Goldin is clearly doing a good job of spreading the word about NASA's contributions to medicine, electronics,

material sciences, chemistry, and manufacturing.

What the article does not make clear is that Goldin and NASA are more or less managing to cover most of their bases even though the agency's budget has not kept up with inflation, as has the funding of other government departments and agencies. Had NASA's budget kept pace, the agency would have more than twice the funding it does today. Nor does the article make evident that it was Congress that ordered five redesigns of the space station; my guess is that such micro-management has cost the program $8 billion.

As far as Goldin's "faster, better, cheaper" credo goes, it has limits as a general paradigm for space missions. Exploring the distant planets still requires large spacecraft such as Galileo and Cassini, and leaving the solar system will require robotic spacecraft that far exceed Cassini in size and, yes, cost.

—Saunders B. Kramer
Gaithersburg, Maryland

I realize that all the great visionaries of the past—Willy Ley, Wernher von Braun, Chesley Bonestell—were enthralled with the idea of manned space stations in near-Earth orbit, envisioning those beautiful wheels, packed with happy little scientists and busy little rocket builders, as stepping stones to the moon and planets. But today the space station is an idea whose time has come and gone; the science it offers can be better done by unmanned vehicles. If Dan Goldin wants to recapture the imagination of the nation's young people and rekindle pride in and support for his agency, he needs to abandon that outmoded concept and direct his manned space efforts toward a rapid and permanent return to the moon.

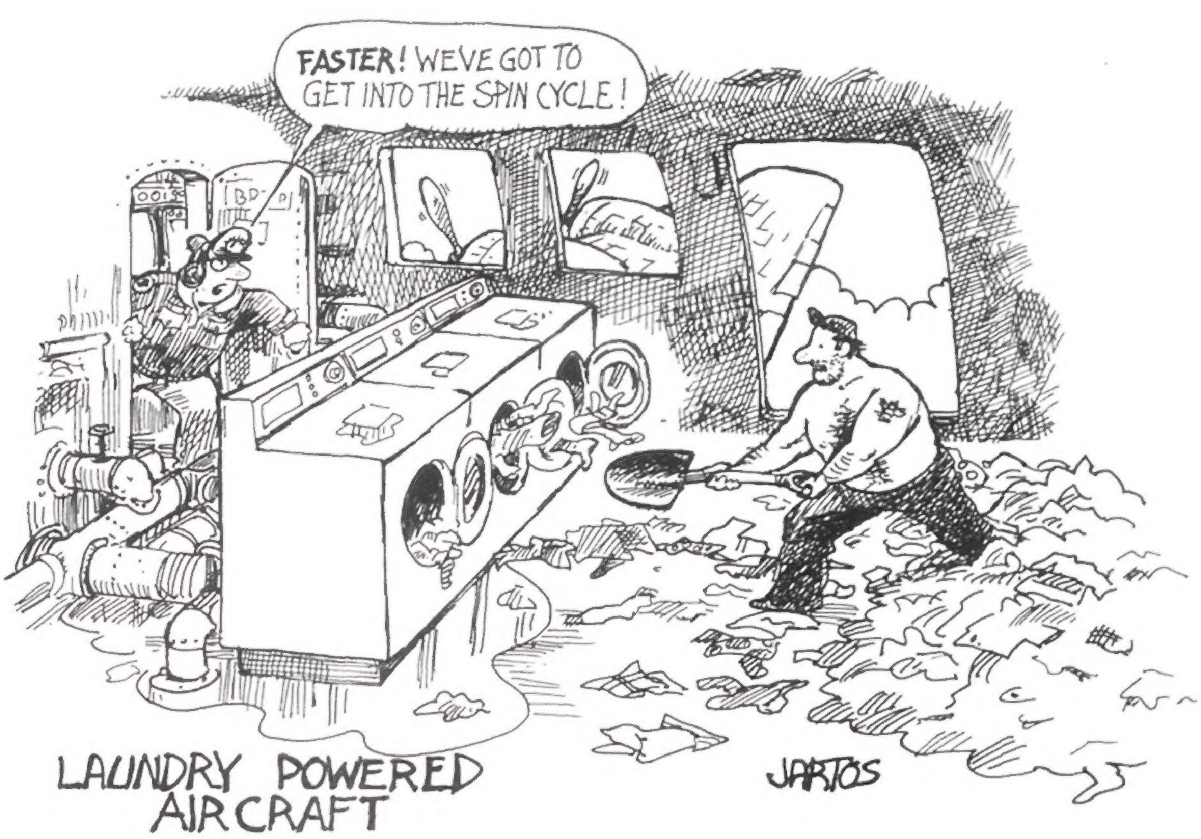
A moon base could serve as the site for a battery of radio and optical telescopes (on the moon's far side, they would be shielded from Earthly interference) or as a platform for microgravity experiments. In addition, probes or manned flights to other planets could be launched more easily from moon's reduced gravity.

Last but certainly not least, a lunar base would accommodate a lot more personnel than a space station could. Kids with an interest in space will be more excited about a career on a lunar base, with its promise of outward expansion, than a berth on some pathetic assembly of sewer pipes in the same old low Earth orbit where their grandparents flew.

—Ed Dempsey
Fort Lauderdale, Florida

You Don't Have to Be Rich (But It Helps)

As a private pilot and aircraft owner who has had the privilege of flying a Stearman, I enjoyed "Back to the Basics" (Oct./Nov. 1994), but I must take issue with Bill Marsano's closing statement, "Private flying today is criminally expensive." Five years ago I bought a 1960 Cessna 210 for $23,000. It had less than 2,500 hours of total use (the typical family car probably averages 500 hours a year). To fly an average of 100 hours a year, I spend around $5,700 to $6,700 (this includes an engine overhaul every 1,500 hours). Now this is not cheap, but it is certainly within reach of people who buy and operate motor homes and sail- and power boats.



"Of course we pay attention to the schedule, sir. That's how we know how late the flights are."

There are even luxury cars more expensive than my fairly typical airplane. Shame on Marsano and others who perpetuate the myth that flying is "criminally expensive."

—Gary Rima
Dallas, Texas

How the War Was Won

It is true that the Norden bombsight was designed to be coupled to the autopilot, thus allowing the bombardier to "fly" the airplane during the bomb run, but when I flew as a lead B-17 pilot with the 447th Bomb Group in 1944 and '45, I never saw that done under combat conditions ("The Secret Weapon," Feb./Mar. 1995). The autopilot, though an excellent device, required considerable adjustment before it would hold the airplane steady. In our bombing group, its principal function in combat was to stand ready to hold the airplane level in the event that the crew had to escape.

For transmitting course change commands directly from the bombsight to the pilot, the technical folks devised a simple left/right needle device called the Pilot Directional Indicator. Once the lead pilot had reached the designated airspeed and altitude, the bombardier would clutch the bombsight into the Pilot Directional Indicator so that the bombsight's left/right corrections showed up as needle deflections. The pilot's job was to keep the needle centered while also keeping the airspeed and altitude nailed. So long as the pilot was not distracted by the attempts of others to kill him and his colleagues, the human hand and eye could outperform the autopilot.

—Richard T. Gillespie
Englewood, Florida

As a World War II bombardier, I think the Honeywell C-1 autopilot probably deserves more credit than it received. The integration of the bombsight and autopilot into a single operating system was highly successful. Some pilots thought they could fly the plane better than the autopilot, but most bombardiers thought just the opposite.

—Herbert C. McKee
Houston, Texas

What's Eric Chaisson's Problem?

According to Eric Chaisson ("Six Ways Back to NASA Greatness," Feb./Mar. 1995), in the "old" NASA, budgets were unlimited, the science was pure and truthful, the women were all strong, the men good-looking, and the children above average.

It's clear to me that Chaisson's whine is really that someone took the money from his pet project and gave it to someone else's.

—Colonel Robert I. Recker Jr.
U.S. Air Force Reserves (ret.)
via e-mail

As a NASA employee, I'm not an entirely disinterested party, but I nonetheless want to pick a bone with Eric Chaisson. He suggests that in this era of "faster, better, cheaper," NASA is hypocritical for not canceling all its large projects, such as the Cassini probe to explore Saturn. But it takes time to change everything; just as Rome wasn't built in a day, it wasn't burned down in a day either. Should we trash every large program we've been working on? Would Mr. Chaisson argue that the Hubble telescope—the epitome of the large, expensive space project—should have been left unfixed?

—Brent Warner
via e-mail

"I can't tell you what's in the dark matter sandwich. No one knows what's in the dark matter sandwich."

Corrections

Apr./May 1995 Table of Contents: The airplane on the cover is an EA-6B electronic warfare craft, not an A-6 bomber.

"The Magnetic North": The airplane on p. 55 is a Piper Super Cub, not a Helio Courier. The Helio Courier was pictured on p. 59.

Feb./Mar. 1995 "Disk Drive" (Soundings): George Neumayr calculates that a 200-foot-diameter disk could hold 756 people, not up to 1,000.

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My Little Margie

For three whirlwind years she wore ruffled gingham dresses and heavy lipstick. She hobnobbed with Hollywood stars and sold war bonds, and Eisenhower himself asked her to visit liberated Europe. But to millions of American servicemen, Margie Stewart was just Margie, the girl next door. Her wholesome smile, which adorned an estimated 94 million World War II war bond posters and letters, reminded them of sweethearts and sisters and of the simple but rich life back home.

"One time I was in France and we were on our way to see about 8,000 GIs," Stewart recalled at a symposium at the American Airpower Heritage Museum in Midland, Texas, last March. "It was pouring rain and we were riding in an open jeep, and it was so cold that we stopped on the way to get a cup of hot chocolate. That made us late. The men had already started to leave, but when they saw us driving up, they all piled around the jeep yelling 'Here's Margie!' The sight of 8,000 men swarming up just to see me gave me goose bumps. It still does." At age 75, Margie Stewart Johnson (she married in July 1945) still smiles broadly as she autographs posters and programs for veterans and other admirers, and listens intently to their wartime remembrances.

A native of Wabash, Indiana, Stewart fell into the job of official U.S. Army poster girl by chance. After a year at Indiana University, she and her roommate moved to Chicago to seek their fortunes. Stewart found hers at a photo studio, where retired Army major Russell Stone needed girls to pose for Johnson outboard motor ads. Other assignments followed, and in 1941 she signed a contract with RKO Pictures and appeared with Pat O'Brien in the 1943 release *Bombardier*.

Stone advised the War Department to dump Uncle Sam from its war bond posters and give the troops a picture of a pretty Midwestern girl—someone just like Margie. Army brass agreed, and Stewart was drafted into poster duty. "I was credited with being more photographed than Betty Grable and Jane Russell put together," she says. GIs responded immediately, flooding the brand-new Pentagon's mail room with requests for autographed photos.

In 1945 she toured France and other liberated countries. "I ate a lot of C-rations and K-rations and washed my face in cold water from a lot of helmets," she says. And Stewart was the first American civilian to visit occupied Germany, wearing civilian clothes—a gingham dress, of course.

She returned to Washington, D.C., on V-J Day. Without a war, there was no need for a wartime poster girl. Stewart wasn't much interested in the movies, so after marrying she settled into family life in California. And although she says she never missed the spotlight, there's a hint of wistfulness in her voice as she recalls those days in Paris. "I couldn't walk into a nightclub," she says, "without the band stopping what they were playing to play something with 'Margie' in it."

—*Damond Benningfield*

BILL CRUMP

UPDATE

X-31 Crash

The NASA accident board has determined that the crash of the X-31 last January (Soundings, Apr./May 1995) was caused by the airspeed probe icing over, which produced an erroneously low reading. The fly-by-wire flight control system, which adjusts the response of the flight controls to airspeed, was set for a low-airspeed mode. The aircraft, which was flying at high speed, became uncontrollable.

Hangar History

WRIGHT-PATTERSON AFB HISTORY OFC.

On Day One of the excavation, archeologists spotted what looked like the remains of a fence post. Within hours, they were sure they had found what they were looking for: the site of the world's oldest hangar.

The hangar was built by the Wright brothers on their flying field at Huffman Prairie outside Dayton, Ohio, near the Simms Station trolley stop. From 1910 to 1916 it housed the Wrights' flight school and aerial exhibition team. Among those who learned to fly there were Henry "Hap" Arnold, who led the Army Air Forces in World War II, Cal Rodgers, who in 1911 made the first transcontinental U.S. flight, and Roy Brown, the Royal Air Force pilot who shot down Manfred von Richthofen in World War I.

Huffman Prairie was swallowed up by Wright Field soon after the United States entered World War I, and the hangar was abandoned and eventually forgotten. In another military base expansion during the early days of World War II, overzealous recruits mistakenly bulldozed the hangar and torched the remains.

Before Orville Wright died in 1948, he journeyed to Huffman Prairie one last time to locate for historians lost features such as the sites of the Wrights' 1904 shed and 1910 hangar. But the topography had changed radically in five decades, and the elderly Orville was no longer completely sure of every location.

In 1990, as part of an ongoing effort to assess the historic features of the nation's military bases, the Army sent a team of archeologists to pinpoint the site of the hangar. Using a thermal remote sensing scanner, developed to detect pre-launch fuel leaks on the space shuttle, the archeologists found subsurface soil disturbances typical of building sites. Hoping to find remnants of a foundation, the team dug shallow slot trenches but came up empty-handed.

Last October a new team hit pay dirt within hours: the remains of the fence post, then two post holes. The hangar was right where Orville had thought it had been. After establishing a grid and painstakingly sifting the soil, the archeologists recovered nails, broken glass, hinges, asbestos roof shingles, and a few pieces of metal that appear to be

from a Wright Model B.

"It becomes evident that aircraft hangars descended from barns," says lead archeologist David Babson. "The contractor the Wrights hired used the same construction techniques you would use on a farm barn, yet one wall is composed of sliding doors to get the airplane in and out, and this is what aircraft hangars are like today."

Further work on the site could reveal details about the Wrights' flight operations, such as how they fueled and serviced their aircraft, where they held ground school, and where they kept their simulator. For now, the soil has been replaced over the dig until more extensive excavation can be undertaken.

—*Phil Scott*

UPDATE

New Space Record

Cosmonaut Valeriy Polyakov returned to Earth last March 22, completing a 438-day stay aboard the Mir space station (Sightings, Apr./May 1995) that set a new space endurance record. The previous record, 366 days, was set in 1988 by Vladimir Titov and Musa Manarov. Polyakov, who exercised up to three hours a day during his stay, appeared either "remarkably fit," according to the *Washington Times*, or "feeble and pale," as the *Washington Post* reported.

JPL

In 1993, the Magellan probe stopped transmitting data from its Venus mapping mission, but scientists will be analyzing the results for years. Earth and planetary scientists at Washington University in St. Louis were perplexed by the frost-like bright areas in Magellan's radar images of Venus' highland regions, where the temperatures reach 750 degrees Fahrenheit. After analyzing the images' microwave emissivity—the characteristics of the surface's energy emissions, which provide clues to surface composition—they theorize that gases from metals such as ore minerals, formed in lowland volcanoes, ride the Venusian winds to the relatively cooler highlands, where they condense and, over millions of years, build up into a thin veneer on highland rocks—a sort of metallic frost.

NASA's Advice Columnists

"As usual, we worry about food first," jokes Lawrence Caroff, executive secretary of NASA's Space Science Advisory Committee, opening the meeting by passing around a sign-up sheet for that night's group dinner. It takes a lot of coffee, sodas, sandwiches, and cookies to keep 18 scientists fueled for three days, sitting in a windowless conference room in Washington, D.C., like a hung jury, listening to briefings, poring over photocopies of budget charts and program summaries, arguing among themselves, and finally—the reason they're here—drafting advice to the agency on where its space science programs ought to be headed.

The morning's first briefing, from NASA deputy comptroller Malcolm Peterson, is grim. The agency's budget is heading south, and, says Peterson, "the tooth fairy ain't comin'." Around the table, everyone looks glum. Many are university scientists whose research is tied to space agency spending, and they're still adjusting to this new NASA, which is slashing its own budget one step ahead of the budget slashers on Capitol Hill. "We haven't been in touch with reality," laments committee member Radford Byerly, a former congressional staffer. "It's not going to be the way it used to be."

After lunch, division chiefs, one by one, give status reports on the agency's astrophysics, space physics, and solar system exploration programs. The presentations recall a joke about a NASA manager standing outside the pearly gates and summing up his life: "First viewgraph, please."

Occasionally, committee members interrupt with a question or worry. Space physics seems to be getting short shrift. Could NASA address that imbalance? The science program's reliance on a proposed launcher called Med-Lite, which is meant to bridge the gap between the small Pegasus rockets and the larger Deltas, seems risky. Several missions are slated to ride on Med-Lites in the late 1990s, but since the vehicle has yet to make its first flight, NASA is putting some pretty expensive eggs in this unproven basket. Should the committee voice its concern?

The little carts of coffee and cookies wheel in and out.

Like the seven other advisory committees that report to the NASA Advisory Council on subjects ranging from aeronautics to the space station, the SSAC meets three or four times annually. There's no pay for committee members, just reimbursement for travel and expenses. Sitting on a committee provides a service to the agency, keeps you in the know, and, members say, lets you influence, in some small way, The Process—whatever that is.

On the third day NASA administrator Dan Goldin stops by. Before he arrives, there is much discussion of how hard the committee should lean on him about cutting science programs. After all, his hands are tied too. Worried that events are moving too fast, they ask Goldin if another, smaller subcommittee could be formed for SSAC members to provide more timely input as NASA makes fast-paced decisions about its science operations, freeing the parent committee to focus on longer-term trends. Goldin agrees, and everybody seems pleased. By the time people dash off to catch flights at the end of the day, writing assignments for the committee's report have been handed out. These will be coordinated by e-mail and then sent to NASA for the agency to either follow or ignore.

—*Tony Reichhardt*

Retirement Party

They came together one last time, packing a ballroom in the officers' club at California's Vandenberg Air Force Base for a salute to a venerable rocket. Spanning 40 years of service, the 500 civilians and Air Force personnel of the Atlas program filled the club last March 31 for a "Mission Complete" banquet. The dinner was held one week after the United States' last Atlas E rocket was launched from Vandenberg carrying a military weather satellite.

For many, it was a chance to see old friends and reminisce about the early days of the cold war, when the Atlas rocket was developed for deterrence against a nuclear face-off with the Soviet Union. "In those days, life was rather urgent," recalled retired Air Force lieutenant general Richard C. Henry, an early Atlas program officer and former commander of the Air Force's space division in El Segundo, California. "We knew that the Soviets were flying ballistic missiles some 2,000 miles" he said, while the United States was still experimenting with converted German V-2 rockets. "The Atlas was the only thing we had to turn to."

Henry came to the intercontinental ballistic missile program in 1955 as a young captain after flying bombers. "It was a hush-hush project," he said. "We'd heard it was a monster missile" that was considered the nation's second Manhattan Project. "In those days there were none of us who could possibly conceive that almost 40 years later we would be using this first-of-a-kind bird to put valuable state-of-the-art satellites into orbit."

On the civilian side, C.R. "Chuck" Harter, director of Atlas operations at Vandenberg for Martin Marietta Astronautics, was among the first to help build and launch the Atlas. Starting with his first assignment in June 1957 as a weights-and-propellant engineer, Harter went on to work on all 281 Atlas launches out of Vandenberg. "There are hundreds of stories that can be told here tonight," Harter said. "About the Atlas that failed and headed toward the town of Santa Maria instead of out over the ocean. The time we launched two Atlases in one day, or the launch demonstration we did for President Kennedy's visit." Harter recalled the time an episode of "Perry Mason" was to be filmed at Vandenberg with an Atlas as part of a scene. As crews were erecting the rocket, Harter said, it fell and broke in two. "The Air Force jumped to secure the area and evacuate everybody. They let three people back in, two colonels and a general—all actors in Air Force uniforms. It was chaos.

"As we close out an era here at

Vandenberg," Harter said in his closing remarks, "we can reflect back on 35 years of serving America with launches for GPS [navigation satellites], weather satellites, and numerous classified launches. And with a final 26 consecutive [successful] launches, what a way to cap a program."

—William H. Boyer

NASA

Atlantis' Ice-Maker Option

A six-pound lump of ice survived a fiery reentry on the shuttle *Atlantis*' port payload bay door last December in a feat described as "an amazing piece of physics" by Jack Boykin, deputy manager of shuttle programs at the Johnson Space Center in Houston. "It's one of those things you'd probably see Mr. Wizard try to show you," he says.

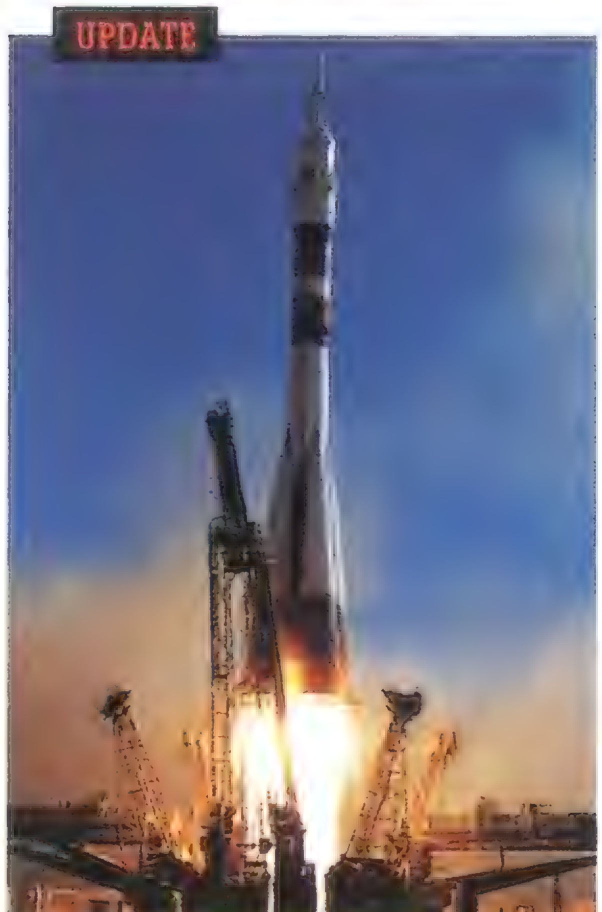
The big ice cube was the oblong "footprint" of a four-foot pencil-thin icicle that formed when water and urine were dumped overboard during the 11-day mission. Normally, waste water "just sprays out into space," says Boykin. This time it froze on a corner of the open door and grew like Pinocchio's nose.

Surface temperatures on the orbiter's nose cone and the leading edges of its wings rise to 2,300 degrees Fahrenheit during reentry, but the shuttle's shape, insulation, and angle of attack so effectively retard the spread of searing heat to the payload bay doors that temperatures there peak at a tepid 180 degrees: A block of ice the size of a sugar cube might melt, but "Anything larger than that and you're going to have some residual ice left over," says John Kowal, a NASA thermal engineer who analyzed the icicle phenomenon after *Atlantis*' return "just to verify in my mind that this is possible."

Before leaving orbit, the astronauts offered to knock the icicle off with the gripper end of the shuttle's robot arm, but the plan was scrapped when the arm's wrist camera failed, effectively blinding its operators. Mission managers finally decided the ice wasn't worth worrying about. Engineers inspecting the orbiter after landing found broken tiles on one of the two orbital maneuvering system engine pods, minor damage they figured was inflicted when a piece of the icicle broke off and struck the pod.

—Beth Dickey

UPDATE



SCOTT ANDREWS

Launched from Baikonur Cosmodrome on a Soyuz rocket last March 14, astronaut Norm Thagard arrived at the Mir space station for a three-month stay that has already been extended ("Mission to Mir," Feb./Mar. 1995). Scheduled to return early in June when the shuttle *Atlantis* was to dock with Mir, Thagard will return later in the month. The Russians have run into trouble getting some docking equipment to the station.

Nose Art Goes Underground

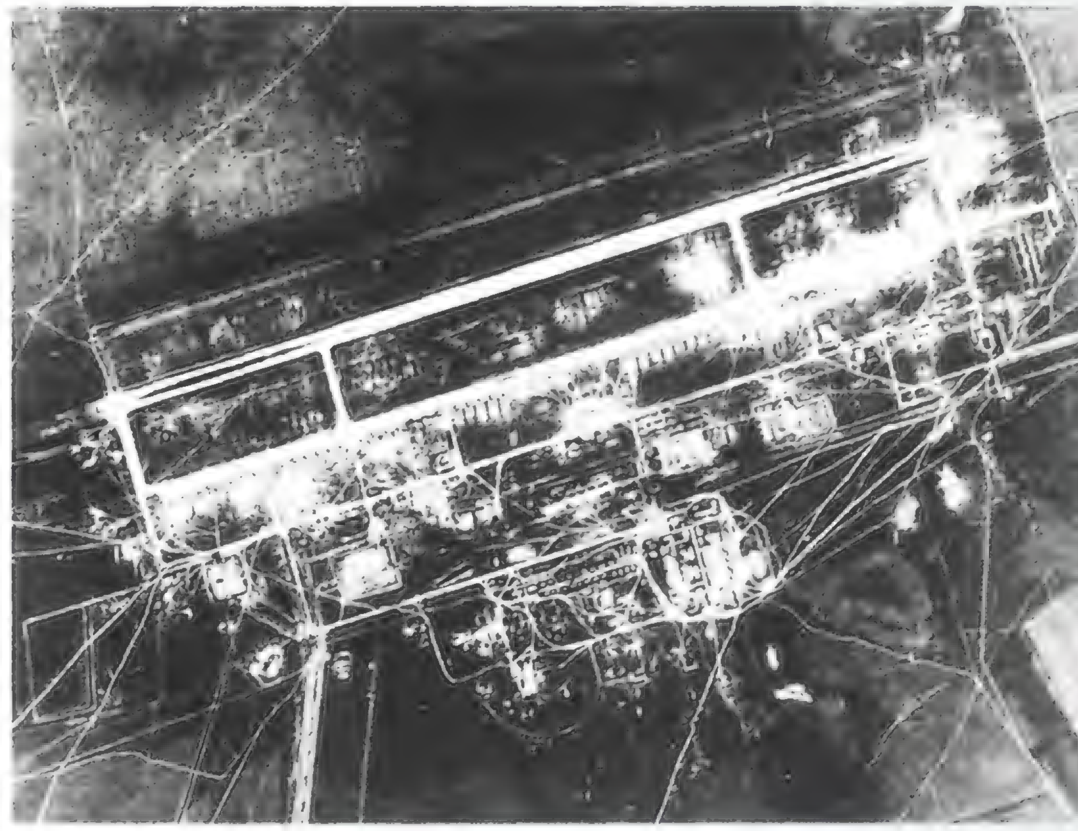
At South Dakota's Ellsworth Air Force Base, investigators examining an underground missile silo have unearthed samples of the successor to World War II aircraft nose art. A painting of a bear, symbolizing the cold war threat posed by the Soviet Union, adorns the 70-ton steel blast door of Lima One, a launch control facility for Minuteman II intercontinental ballistic missiles.

According to Daniel Friese of the Department of Defense's Legacy Resource Management Program, the bear is one example of "blast door art." Such paintings are the work of "missileers"—crews assigned to the 15 command capsules buried 65 feet beneath the surface. The two-man crews, on duty for 24-hour shifts, were responsible for 10 silos, each housing a nuclear-tipped missile ready for launch. Crews decorated the interiors of their underground command posts "probably for the same reasons that bomber crews decorated the noses of their aircraft," says Friese.

Most of the paintings reflect esprit de corps, patriotism, or macabre humor. In one, a bald eagle grasps a missile in its talons. Beneath it is the number 68 (for the 68th Strategic Missile Squadron of Ellsworth's 44th Missile Wing) and the words "On Time, On Target!" Another depicts a map of the state of South Dakota with a star to show Ellsworth's location. Above hills covered with pine trees (representing the Black Hills) soar two eagles and three missiles. A third shows a pizza box adorned with a missile silhouette. The caption: "World-Wide Delivery in 30 Minutes or Less—or Your Next One Is Free."

The latter painting adorns Delta One, a Missile Alert Facility that may someday be operated by the National Park Service. Friese says negotiations are under way to have a launch control facility and missile silo declared a National Historic Site. The site would then be turned over to the Department of the Interior, which would have the responsibility of preserving this legacy of the era when the threat of mutual nuclear destruction seemed quite plausible.

That threat was substantially reduced in 1991 when the United States and the Soviet Union signed the Strategic Arms Reduction Treaty, which provided, in part, for the systematic dismantling of a number of facilities like these Minuteman II launch sites. Friese says that within the year, contractors will fill the Ellsworth capsules with sand, permanently seal the blast doors, and place a concrete cap above each site, permanently blocking entry. Next on the list is Missouri's Whiteman Air Force Base, followed by missile sites in Wyoming, North Dakota,



DEPARTMENT OF DEFENSE (2)

A sampling of satellite reconnaissance photos declassified by the National Reconnaissance Office last February, these images of Soviet air fields dramatize the progression in reconnaissance optics. The CIA's Project Corona satellites began reconnaissance under the cover of the Discoverer space science program in 1960. On August 18, Discoverer XIV launched the first camera-equipped Corona from Vandenberg Air Force Base in California. The satellite's camera, with a resolution factor of 50 to 100 feet, captured a hazy image of Mys-Schmidta air base on the Kamchatka Peninsula. According to presidential secretary Andrew Goodpaster, the first images were "like the dog that walks on its hind legs, remarkable that it happens at all." The five-foot-resolution photo of a Soviet bomber base in Kazakhstan, taken by a KH-4B camera on board a Corona on August 20, 1966, enabled photo interpreters to determine the length of the runways, size of the buildings, location of the nuclear arms bunker, and number and type of aircraft (about 40, mostly Tu-16 bombers). Initially, parachute-equipped canisters of exposed film were deployed by the satellites and snatched in mid-air by C-119 and C-130 aircraft. In 1976, with the launch of the KH-11, imagery was instantaneously relayed to a ground station. The 800,000 photos, taken between 1960 and 1972, are being catalogued by the National Archives and should be available to the public by mid-1996.

and Montana, all of which have examples of blast door art.

Part of Friese's task is to help "preserve natural or cultural resources on DoD land." In this case, preservation involves photographing the blast door art at the targeted sites. "By the end of the year, we should have a full recordation of all of the Minuteman II artwork," says Friese, "and we will then offer it either to the Smithsonian, to the Air Force Museum, or to the Air Force Academy."

—Stan Solomon

Back in the Data Stream

When the revamped Hubble Space Telescope went back to work in December 1993, Melissa McGrath breathed a sigh of relief. Since the telescope was launched in 1990, the astronomer at Baltimore's Space Telescope Science Institute had hesitated to tell people what she did for a living. Says McGrath, "The common reaction was 'It's not working, is it?' "

McGrath, who was then using the telescope to study the atmosphere of Jupiter's moon Io, knew it was a bad rap. Even with flawed optics, McGrath recalls, "we were doing cutting-edge science, things we could never do before HST." But she could never get that message across. "I think they thought we were being defensive—that we had to say it worked well, but really, NASA had wasted two billion dollars. For about three years, if you read anything about space, astronomy, or NASA, they always referred to 'the failed Hubble telescope.' We felt like you couldn't afford to make any mistakes."

Neither could the astronauts who repaired the Hubble. Like many of her colleagues at the institute, McGrath stayed up all night to watch the mission. One crew member, Kathy Thornton, had been a fellow graduate student of McGrath's at the University of Virginia. When the task was accomplished, McGrath and her colleagues finally had reason to celebrate. "I've sort of forgotten about it," she says, "because going through the comet crash last summer was even better." Indeed, the Hubble's images of comet Shoemaker-Levy 9 smashing into Jupiter made front-page news.

Since then, McGrath's colleagues have been raking in so much data that she can barely keep up with the findings, and McGrath herself is continuing to study the atmospheres of Io, Europa, and Saturn's satellite Titan. Best of all, when she tells people that the Hubble works, they believe her.

—Andrew Chaikin

UPDATE

Hide and Seek at Groom Lake

The Air Force has closed to public access an additional 3,972 acres surrounding its top-secret Groom Lake facility in Nevada (Soundings, Dec. 1994/Jan. 1995). In 1993 the Air Force requested that the Department of Interior close off the land to protect the "safe and secure operation" of the 3.5 million-acre Nellis Air Force range complex, where the U-2, SR-71, and F-117 were test-flown. Last April the Bureau of Land Management transferred control of the acreage to the Air Force until November 2001.

You've Come a Long Way, Barbie!

MATTEL, INC. (3)

Over the years Barbie has worn many hats. In 1990 she was an Air Force fighter pilot (above), in 1993 a Desert Storm veteran, and in 1994 an astronaut.

In 1959 she was a teenage fashion model, a ponytailed blonde clad in high heels and a zebra-striped bathing suit. Thirty-six years later, Barbie, the world's best-selling doll, has earned a place of honor at the National Air and Space Museum—fittingly the most visited museum in the world.

Highly ambitious and blessed with a boundless ability to change with the times, Barbie has moved well beyond the fashion world to make her mark in dozens of professions, including medicine, business, journalism, and education. Over the years she has also worked for the airlines, the Air Force, and NASA, and it was these achievements in aviation and space that led to her recognition at the Museum. Starting in June and running through September, a group of 37 aviation- and space-theme dolls from the Barbie line will go on display in an exhibit titled "Flight Time Barbie: Dolls from the Popular Culture Collection of the National Air and Space Museum." The Barbie exhibit "really is an outgrowth of our work on forming a popular culture collection," says Mary S. Henderson, chair of the Museum's department of art and culture. In an agreement with the Museum, Mattel, the creator and manufacturer of Barbie, is donating 13 of the exhibit dolls.

Since Barbie's creation in 1959, she has become a pop culture icon. Over one billion dolls (including Barbie's friends and family) have been sold; placed head to toe, they would circle Earth more than 11 times. Worldwide, two dolls from the Barbie line are sold every second. Though Barbie has often led a very sophisticated life over the years, her message has always been simple. "Barbie is letting little girls know that they can do anything," says Lisa McKendall, Mattel's director of marketing communications.

Barbie first broke into the airline business in 1961, when she worked as a stewardess for American Airlines. At a height of only 11 and a half inches, Barbie was far shorter than other stewardesses, but her trim figure was perfect for showing off the American Airlines uniform: a white blouse with a navy blue skirt and jacket. In her hand, she gripped a zippered American Airlines flight bag—Barbie-size, of course. Throughout her long airline career, Barbie would wear the uniforms of Pan Am, Braniff, and United. In 1964, Barbie's boyfriend, Ken, also appeared as an employee of American Airlines, though his smart captain's uniform announced his higher rank. The American Airlines Barbie and Ken are both included in the exhibit, along with astronaut Barbie and Ken dolls that were released in 1965, during the heyday of the U.S. space program.

In addition to dolls, the exhibit includes some of Barbie's must-have accessories, such as Barbie's Friend Ship, a play model of a United Airlines jet that was released in 1973. Touted as the "airplane for everyone in Barbie's world," the Friend Ship came with a mobile serving

cart, stewardess smock, and "realistic window views."

The well-rounded exhibit, a testament to Barbie's self-confidence and courage, also shows off her military experience: She has served as an Air Force pilot, a Desert Storm soldier, and an Air Force Thunderbird squadron leader. (Ken too has broken some new ground; in 1990 he appeared for the first time as a flight attendant.)

The final doll in the exhibit is an astronaut Barbie that was marketed last summer to celebrate the 25th anniversary of the Apollo 11 moon landing. A Mattel press release trumpeted: "One small step for Barbie, one giant leap for toy-kind." What's next on Barbie's horizon? Surely a trip to Mars. If her past is any indication, it'll happen sooner than we think.

—*Diane Tedeschi*

Aim High

"To me, there's nothing more exciting than going faster than the speed of sound at 500 feet and then standing an airplane up on its tail and going straight up to 35,000 feet before you run out of airspeed." So rhapsodizes F-14 pilot Susan Still (below) in an educational documentary titled *Visions of Success*, which profiles women who have excelled in the fields of aviation and space.

"There's a lot of careers that girls just don't know about," says the film's creator, Patricia Woodside, who is the Museum's chief of film and video production. It is Woodside's hope that *Visions*, a work in progress targeting a junior high audience, will make students aware of the many doors open to them. Woodside, who began working on the documentary two years ago, has so far filmed and interviewed Still, a Navy pilot now in NASA's astronaut program, and Boeing 737 pilot Cindy Berkley, the first woman captain at United Airlines. If Woodside can secure the $50,000 funding that she needs, she'd like to finish the film by including three more women: an astrophysicist, an aerospace engineer, and an airline mechanic.

CAROLYN RUSSO

"I'm a department of one," says Woodside, which means that she must hire a director, grip, and camera and sound technicians before heading out on location. Once the hour-long film is completed, she hopes to get it aired on a cable network and have 500 videocassettes distributed to schools, where teachers can offer additional encouragement. "Hopefully, there will be little girls out there that will realize they can do more," says Woodside.

—*Diane Tedeschi*

Museum Calendar

Except where noted, no tickets or reservations are required. To find out more, call Smithsonian Information at (202) 357-2700 Mon.–Sat., 9 a.m.–4 p.m.; TTY: (202) 357-1729.

June 3 "Binoculars! Telescopes! Astronomy!" Learn to choose, use, and care for astronomical instruments during this free workshop. Briefing room, 11:00 a.m. to 4:00 p.m.

Monthly Sky Lecture. "Where's My Wandering Polestar Tonight?" Join Einstein Planetarium director James Sharp for an exploration of the strange wobbling of Earth's axis. Einstein Planetarium, 9:30 a.m.

June 10 Boomeranging on the Mall. Learn the aerodynamics and flight principles necessary to use a boomerang. From noon to 4:00 p.m. (boomerangs will be provided). Free tickets to this event will be handed out in the Museum beginning at 11:00 a.m.

June 14 Exploring Space Lecture. "The 1997 Servicing Mission: New Scientific Horizons for the Hubble Space Telescope." A lecture by Mark Clampin of the Space Telescope Science Institute. Einstein Planetarium, 7:30 p.m.

June 17 "Skylore From Around the World." Join Einstein Planetarium's Cheryl Bauer as she recites ancient stories about the stars and reveals their meanings. Einstein Planetarium, 10:00 a.m.

ARTIFACTS

NASM

On April 4, 1933, the ZRS-4 Akron, *a U.S. Navy rigid airship, crashed during a thunderstorm 20 miles off the coast of New Jersey. Only three of the 76 crewmen survived. Moved by the sad event, R.P. Hitchcock, who lived close to the Goodyear-Zeppelin air dock where the airship was built in Akron, Ohio, wrote the lyrics to "The Wreck of the* Akron *Dirigible." This original sheet music was donated to the Museum in 1993 by R.P.'s grandson, Jim Hitchcock. Shortly after the crash, R.P.'s sons, local musicians Earl and Ford, performed the entire song live on an Akron radio station, including this melancholy third verse: "Each face was set and grimly, each strived with might and main/ To cheat the storm's wild fury, and right the ship again/ Each man was fighting bravely, for his loved ship and life/ Each thought of mother sweetheart, of loved ones or of wife/ When suddenly the crashing, they knew the storm had won/ All plunged into the ocean. Amen—God's will be done."*

Unfortunately for the airmen who flew these dirigibles, tragedies were not rare. In 1925, the Navy's ZR-1 Shenandoah *tore apart during a storm, and the* Akron*'s sister ship, the ZRS-5* Macon, *crashed in 1935. Indeed, "The Wreck of the* Akron *Dirigible," along with a composition about the downing of the* Shenandoah, *updated a genre of what might be called "transportation wreck music," which includes the train accident tale "Casey Jones" and songs about the 1912 sinking of the* Titanic.

The Long Way Home

I was a pilot for Pan American Airways for 28 years, and one of the reasons I was drawn to that fabled airline was its exciting history. Once I donned the distinctive black and white uniform, I became even more absorbed by the tales of Pan Am's early glories, some of them told first-hand by the pilots with whom I flew. One story I found particularly fascinating was that of the unscheduled, almost round-the-world journey made by the Pacific Clipper, *a Boeing B-314 flying boat under the command of Captain Robert Ford. The* Clipper *was part of Pan Am's growing new service that linked the far corners of the Pacific Ocean. Six days out of its home port of San Francisco in 1941, the huge triple-tail aircraft was just hours from getting its 12 passengers to their destination of Auckland, New Zealand, when the crew received a startling message: The Japanese had attacked Pearl Harbor. The route home was irrevocably cut.*

A few years ago I decided that the saga of the Pacific Clipper's *flight back to the United States was one of the Pan Am chronicles that deserved retelling. When I set out to research the story, I discovered that of the 10 crew members, only the captain was still alive and able to recount what had happened. Last year I made the journey to 88-year-old Robert Ford's ranch in northern California and found a spirited man who regarded that long-ago adventure as merely a part of his job. Though he had lost his hearing and was frail from his fight with cancer, Ford spun a spellbinding story, most of which follows. Ford died in October 1994, the last of the crew of the* Pacific Clipper.

John Poindexter was the radio operator. We were over the South Pacific just after dawn when the message came in, and I saw his eyes widen as he wrote the characters on the pad in front of him. Pearl Harbor had been attacked by Japanese warplanes and had suffered heavy losses; the United States was at war. We were stunned. We looked around at each other and realized there was no going back over the Pacific. I ordered radio silence, then posted lookouts in the navigator's blister. Two hours later we were in the Auckland harbor.

Every day for a week the whole crew showed up at the communications room at the U.S. embassy in Auckland waiting for a message from Pan Am headquarters in New York. Finally word came: We were to try and make it back to the United States the long way—around the world westbound.

For Ford and his crew, it was a daunting charge. Facing a journey of more than 30,000 miles, over oceans and lands that none of them had ever seen, they would have to do all their own planning and servicing, scrounging whatever supplies and equipment they needed—all this in the face of an erupting world war in which political alliances and loyalties in many parts of the world were uncertain at best.

Our first assignment was to return to Noumea [a Pan Am stop on the main island of New Caledonia, en route to New Zealand], back the way we had come over a week earlier. We were to pick up the Pan American station personnel there, then deliver them to safety in Australia. When we arrived I told the station manager to round up all his people and get them to the dock within an hour. With them and a barrel of engine oil, we took off for Gladstone, Australia.

I was wondering how we were going to pay for everything we were going to need on this trip. We had money enough for a trip to Auckland and back east to San Francisco, but this was a different story.

When we arrived in Gladstone, there was a great deal of interest in the *Clipper.* A young man who was a banker came up to me and out of the blue said, "How are you fixed for money?" I told him we were broke, and he said, "I'll probably be shot for this." But he went down to his bank on a Saturday morning, opened the vault, and handed me 500 American dollars. Since Rod Brown, our navigator, was the only one with a lock box and a key, we put him in charge of the money. That $500 financed the trip all the way to New York.

The next day we headed straight northwest, across the Queensland desert for Darwin. For the entire 10-hour flight none of us saw a river big enough on which to set down should anything go wrong. Any emergency would have forced me to belly-land the airplane onto the desert, and our flight would have ended.

In Darwin the crew managed only a few hours of fitful sleep before takeoff, but Ford was anxious to be under way. He planned to fly across the Timor Sea to the Dutch East Indies (now Indonesia), hoping that Java and Sumatra remained in friendly hands. News of the progress of the Japanese forces was sketchy at best, and Ford was trying to stay at least one step ahead of the conflict that was spreading southward like a brushfire.

As we approached Surabaya, the second largest city on the island of Java, a single Brewster fighter rose to meet us. Moments later it was joined by several more. We flashed the recognition signals that I had received in Australia, but they must have been inaccurate because the Dutch pilots didn't recognize us. Because of a quirk in the radio system, we could hear them but they couldn't hear us. What we heard was their discussion of whether or not they should shoot us down. I made a very careful approach.

As I neared the harbor I could see that it was filled with warships, so I set the *Clipper* down in the smooth water just outside the harbor entrance. We turned around to head back in and a launch came out to meet us, but instead of giving us a tow or a line, it stayed off about a mile and the crew kept waving us on. Finally, when we got farther into the harbor, they came closer. It turned out that we had landed right in the middle of a minefield, and they weren't about to come near us until they saw that we were through it.

We were feeling pretty lucky until we were told that we would be unable to refuel with 100-octane aviation gas. What little there was had been strictly rationed and was reserved for the military. There was automobile gas in abundance, however, and the British supply officer told me I was welcome to whatever I needed. We figured it was either that or leave the airplane to the Japanese. The next leg of the journey would be many hours over the Indian Ocean, and there was no hope of refueling elsewhere.

The flight engineers, Swede Roth and Jocko Parish, cooked up a plan. They transferred all the remaining aviation fuel to the two fuselage tanks, and filled the remaining tanks to the limit with the lower octane automobile gas. We took off from Surabaya on the 100-octane, climbed a couple of thousand feet, and pulled back the power to cool off the engines. Then we switched to the automobile gas and held our breath. The engines almost jumped out of their mounts, but they ran.

We continued northwest across the Sunda Straits, paralleling the coast of Sumatra and then crossing the vast expanse of ocean. We had no aviation charts or maps for this part of the world; the only navigation information available to us was the latitude and longitude of our destination at Trincomalee, on the island of Ceylon [now Sri Lanka]. Using these coordinates and drawing from his memory of Navy charts, Rod Brown [the navigator] was creating his own Mercator maps of south Asia. I was not only worried about finding the harbor, I was concerned about missing Ceylon altogether.

When we thought we were getting close, we ran into some low scud, so we descended. We wanted maximum visibility to permit picking up landfall at the earliest moment—we didn't want to miss the island. All of a sudden there it was, right in front of us: a Jap submarine! We could see the crew running for the deck gun. Let me tell you, we were pretty busy getting back into the scud again.

KAREN BARNES/WOOD RONSAVILLE HARLIN, INC

For the next several days across thousands of miles, the Clipper's *crew found the hospitality of the British Royal Air Force at every port they visited—Ceylon, India, Bahrain, and Sudan. It took them a full day to cross Africa, flying from the Nile southwest to the Congo River, which they followed south to Léopoldville, now the Zairian capital, Kinshasa.*

When we finally stepped ashore, it was like stepping into a sauna. The heat was so oppressive it drained any energy we had left. We were feeling pretty forsaken until two friendly faces greeted us at the dock. A Pan American airport manager and a radio officer had been dispatched to meet us, and one of them handed me a cold beer. That was one of the high points of the whole trip.

The next morning the terrible heat and humidity had not abated a bit. The airplane was loaded to the gunwales with fuel, plus the drum of oil we had brought aboard at Noumea. It was, to put it mildly, just a bit overloaded. We headed downstream into the wind, going with the six-knot current. Just beyond the limits of the town the river changed from a placid downstream current into a cataract of rushing rapids. I held the engines at takeoff power while we gathered speed.

The heat and humidity and our tremendous gross weight were all working against us. I had to get the machine off the water before the cataract, so I tried rocking the hull with the elevators, trying to lift the nose and get up on the step. Just before the rapids, the hull lifted free.

Now we were in steep gorges beyond the waterfalls. It was like flying in a canyon. The airplane staggered and her wings bowed, clawing for every inch of altitude. The engines had been at takeoff power for nearly five minutes and their temperatures were rapidly climbing above redline. I wondered how much more abuse they would take. Finally we started to climb. When we were clear of the walls of the gorge, I pulled the throttles back to climb power and turned west toward the Atlantic.

After being airborne for over 20 hours, the Pacific Clipper *landed in the harbor at Natal, Brazil, just before noon. Late that same afternoon the crew took off for Trinidad, finally landing at three the next morning. The final leg to New York was almost anticlimactic. Just before six on the morning of January 6, 1942, the control officer in the marine terminal at La Guardia airport was startled to hear his radio crackle to life with the message* "Pacific Clipper, *inbound from Auckland, New Zealand, Captain Ford reporting. Due arrive Pan American Marine Terminal La Guardia seven minutes."*

They had touched all but two of the world's seven continents, crossed the equator four times, flown 31,500 miles in 209 hours, and made 18 stops under the flags of 12 different nations. They had also made the longest nonstop flight in Pan American's history, a 3,583-mile crossing of the south Atlantic from Africa to Brazil. Radio operator John Poindexter was originally scheduled to accompany the Pacific Clipper *to Los Angeles and return to San Francisco the same evening; he had even asked his wife to hold dinner. But the regularly scheduled radio officer became ill, and Poindexter had to take his place on the flight headed for New Zealand. His one shirt was washed in every port the* Clipper *visited.*

In a final bit of irony, after almost nine days of flying, the Pacific Clipper *had to circle the New York harbor for nearly an hour—no landings were permitted until official sunrise. The craft finally touched down just before seven, the spray freezing as it hit the hull. The* Pacific Clipper *had made it home.*

—Robert Ford
as told to John A. Marshall

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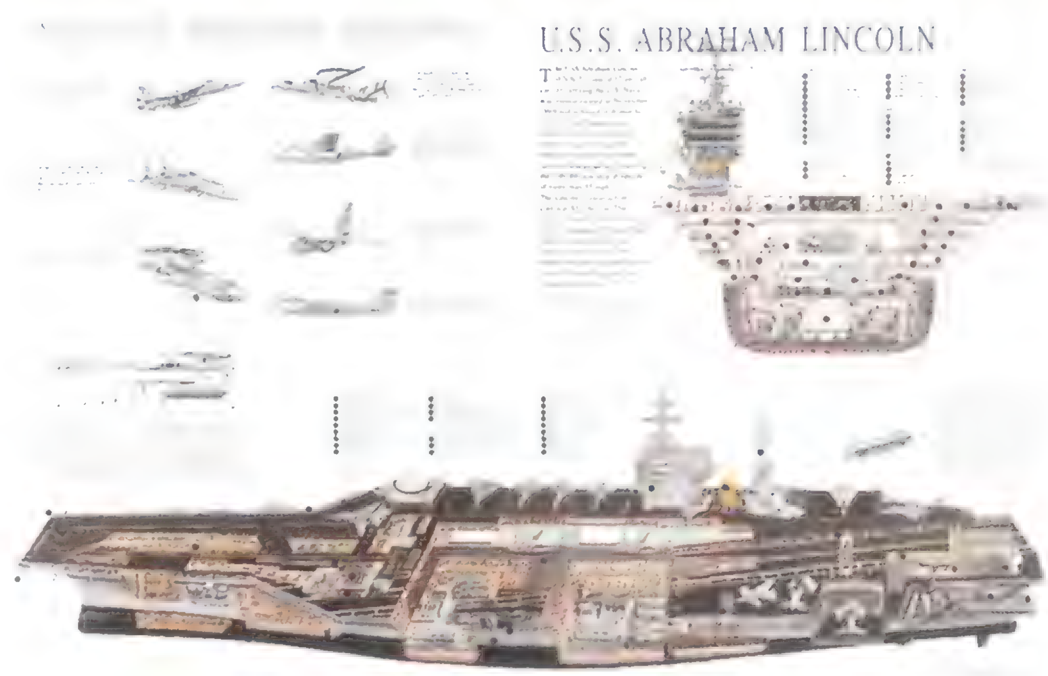

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The Man in the Homburg Hat


BILL FIRESTONE

In the summer of 1944, as an Air Transport Command ferry pilot based at Great Falls, Montana, I flew all types of aircraft from U.S. factories to national and overseas sites. I would ferry, say, a North American P-51D from California to New Jersey, then pick up a Republic P-47D from Long Island and deliver it to a training base in North Carolina, then pick up a B-17 in Florida and fly it to Africa. Eventually, I managed to fly every type of aircraft in the Army Air Corps.

One day I was sent to the Bell factory at Niagara Falls, New York, to pick up a new P-63A Kingcobra and fly it back to Great Falls and then on to Fairbanks, Alaska, for delivery to the Russians under the Lend-Lease program. I had made this flight at least 20 times. Usually I'd stop at my hometown, Toledo, Ohio, for 20 minutes and visit with my family, who would come out to the airport to see me and whatever I was flying. (These short visits were illegal; we were supposed to stop only at certain authorized airports for fuel or rest.)

When I arrived at the Bell factory, the operations officer gave me new orders: I would be ferrying a new type of Kingcobra, an orange RP-63A, to Dayton, Ohio. The aircraft was experimental as well as secret. Bell pilots had nicknamed it the Pinball.

It was more than 2,000 pounds heavier than production P-63s, and it had armor plating around the cockpit and engine, which was located behind the cockpit. The Pinball carried no guns, but it had bulletproof glass. It also had hundreds of little sensors embedded in its quarter-inch-thick aluminum skin. The idea was that the RP-63 would fly in mock combat with bomber-gunners, who would fire at it with different-colored plastic bullets that powdered on impact. Each hit would register on a counter in the cockpit, hence the Pinball moniker.

The factory pilots warned me that the big orange Pinball took a while to get off the ground, that it landed at 150 mph instead of 100, and that it flew like a truck. *If the Wright brothers could see what their invention has come to,* I thought, *they'd be spinning in their graves.*

I climbed in, fired up the engine, taxied to the runway, and began my takeoff roll. The Pinball used up about 7,000 feet of runway and took forever to get up to cruise speed. By the time I arrived at Dayton's Wright Field, I was eager to get it on the ground and be rid of it.

Scratching his head in amazement, a ground crewman waved me to a stop at the operations area. As I climbed out of the Pinball, a group of men in air corps uniforms of assorted high ranks started walking toward me.

As a measly 22-year-old first lieutenant, I was not accustomed to addressing a clutch of full-bird colonels, two-star generals, and a three-star general, along with other officers and a few civilians. I began by saluting. Three-star asked me what the hell I was flying. The others inspected the curious orange airplane.

I showed the general my delivery orders, which stated that this was some sort of secret aircraft, and gave him a simple briefing on the Pinball. He slowly shook his head in disbelief.

Then, as the others drifted away, an elderly man in a suit and Homburg hat started asking me about rate of climb, altitude, weight, airspeeds, and runway required to get airborne. These were interesting questions, coming from a civilian. *Maybe he's an old World War I pilot or engineer,* I thought.

When I walked into Operations, I asked the major at the desk who all those people were. He said there was some sort of meeting and presentation going on. "Who was the old guy I was talking to?" I said. "He asked a lot of pertinent questions for a civilian. Is he a former pilot?"

"Are you talking about the old guy in the Homburg hat?" the major said. "That's him," I replied. "Well, son, you were talking to Orville Wright. You remember the Wright brothers from your history books, don't you?"

My jaw dropped. "You mean THE Orville Wright? I thought the Wright brothers were dead!"

"Nope, you were talking to a real aviation legend," the major said. By the time I realized that I had no camera and had missed my chance to ask for an autograph, the group on the runway was walking into another building. I ran to the window to get one last look at the soft-spoken old man in the Homburg hat who had asked such educated questions about one of the world's oddest airplanes.

—Ben L. Brown

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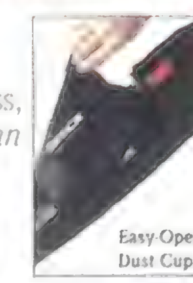

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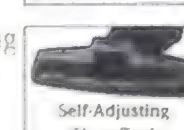

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DEATH OF THE BEAST

SAYING GOODBYE TO A TRUSTY OLD COLD WARRIOR.

by Ralph F. Wetterhahn

Ken Curry, 49, a veteran of 157 air combat missions and recipient of a Distinguished Flying Cross, looked out the window of his motel room and saw rain lashing the streets. It was 5:30 in the morning, and two and a half inches had fallen on Tucson during the night. *Good day for an execution*, he thought.

Curry had taken a few days off from his job as general manager for Petersen Aviation in Van Nuys, California. Someone had told him that one of the B-52Ds he had flown in Vietnam was now at the Aircraft Maintenance and Regeneration Center in Tucson, and Curry had come to witness the end of its career as a cold warrior.

At 6:30 Curry arrived at AMARC, situated at Davis-Monthan Air Force Base. Encompassing 2,600 acres, AMARC is the facility where the U.S. military stores aircraft and Titan II missiles it has removed from service. Many aircraft and parts will be refurbished; last year 197 aircraft and 28,500 parts were made operational. But AMARC has a second mission: destroying aircraft—often perfectly good ones.

In 1993 the center began carrying out the terms of the Strategic Arms Reduction Treaty. Signed in 1991, START requires in part that the United States and Russia, Byelarus, Kazakhstan, and Ukraine reduce the total number of strategic nuclear delivery vehicles—intercontinental and submarine-launched ballistic missiles plus heavy bombers—to 1,600. To disable the bombers visibly and permanently, as the treaty requires, AMARC personnel use a six-and-a-half-ton steel blade deployed from a crane to chop them up. Afterwards, the remains are left in place for 90 days so that the treaty signatories can use satellite overflights to verify the destructions.

AMARC was charged with destroying 217 B-52Cs, Ds, Es, and Fs by December 15 of last year. Ten days before the deadline, all that remained were eight B-52Ds. Today the guillotine would descend on tail number 666. Nicknamed "the Beast" because of the Biblical reference to that number ("Let him that hath understanding count the number of the beast…and his number is six hundred sixty-six," *Revelations* 13:18), the bomber

Photographs by Chad Slattery

had logged more than 400 combat missions during the Vietnam war—a total of 13,000 hours in the air. It had also spent countless hours on alert, armed with nuclear bombs capable of reducing a city to cinders in one blinding flash. Now it was down to its last hours as a symbol of American might.

Finally the rain let up. AMARC equipment operator Robert Conrad drove his crane through the mud beneath overcast skies toward the Beast. Two men worked stabilization lines attached to the upper corners of the blade. Supervising the operation was David Cowan, who a year earlier had driven the crane during the first elimination of a B-52.

Cowan and his crew are used to operating the forklifts, semi-trailers, and cranes at AMARC, but the destruction of the heavy bombers required some refinements of those skills. The operation entails reeling in the cable holding the blade until it is 80 feet above the target, then dropping it at four precise points on the bomber—the tail, each wing, and the fuselage section aft of the wings. Only then are the terms of the START treaty satisfied.

The guillotine system consists of the blade and, 25 feet above it, a half-ton "headache ball." The ball keeps the length of cable above it taut. Once the blade lands, the crane operator must stop the cable release before the headache ball hits the bomber; if it does, the whole cable will go slack, and the released tension will quickly travel up the

Reunited with his old bomber after 23 years, Ken Curry was awed by its destruction, a routine that is brutally simple. The B-52s are chopped at four places: two points on the fuselage and once at each wing.

cable and cause it to snarl, or "bird nest," at the drum.

Cowan says that the first time he dropped the blade, "There were about 200 people out here. I was on pins and needles. It was an emotional thing to see a perfectly good aircraft turned into nothing, but here we had them being destroyed one-for-one with the Russians. That made all the difference."

Not all cuts have gone smoothly. One turned into a black comedy of errors. The blade chopped a hydraulic line that still held pressurized fluid, and the fluid sprayed out and ignited. Coincidentally, a group of Tucson firemen had been invited to witness the chopping, but the fire truck they had driven carried no water. The base's fire department had to be called to extinguish the blaze.

Ken Curry threaded his way through the mud to the side of the Beast. Rain dripped down its skin. He made his way forward to the crew hatch and climbed aboard. It had been 23 years since he had last flown the Beast.

"Oh, déjà vu. What a feeling," he said as he mounted the entry ladder. He made his way up alongside the navigation bay, then past the "black hole," the electronic warfare officer's position, and forward into the cockpit. "It's pretty much all still here!" he shouted to the AMARC crew members waiting near the tail. Only a few of the instruments were missing, presumably returned to service in another airplane. Curry slipped into the pilot's seat, spun the trim wheel, took the control yoke and throttles in hand, and was suddenly 23 years and 10,000 miles away.

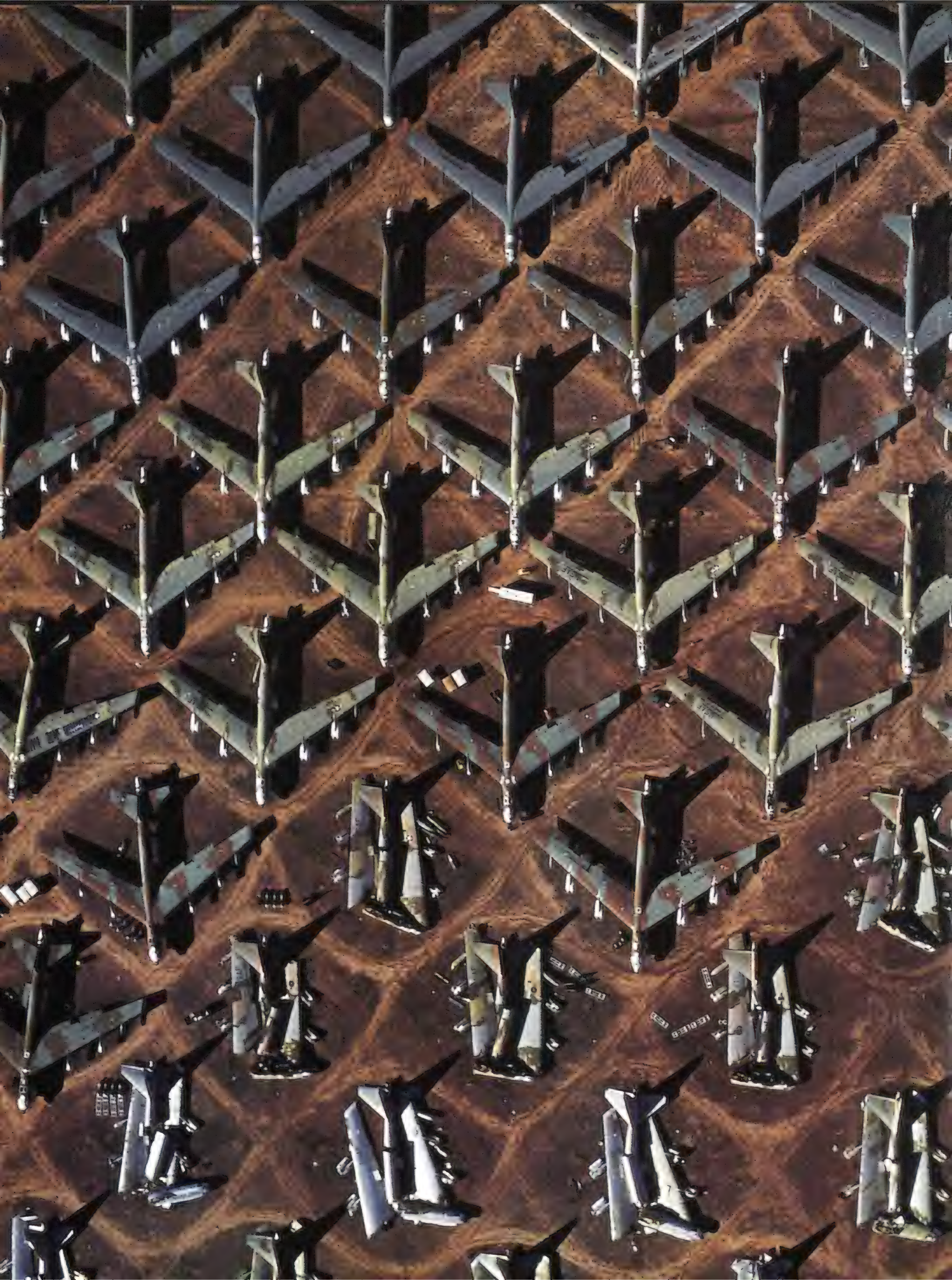
He recalled how it felt, steering 225 tons of aluminum, fuel, and explosives over enemy territory. One mission in particular stood out. It was April 1972, and he was piloting a B-52D with the call sign Aqua Two over North Vietnam, along with two other bombers. Though Curry spotted a few surface-to-air missiles in the area, the three bombers were able to reach the airfield they had targeted and drop their loads.

Suddenly a bright flash seemed to fill the

MICHAEL R. HOYT

Using forklifts, semi-trailers, and bucket loaders, AMARC personnel David Cowan, Jimmy Carter, Robert Conrad, and James Watts (left to right) keep the center's disparate inventory moving. At any given time, AMARC houses everything from propellers and landing gear (above) to Titan missiles.

Overleaf: After the Stratofortresses have been hacked up, they are left in place for 90 days so that the START signatories can use satellite overflights to verify the destructions.



MICHAEL R. HOYT

Once the Russians have verified the executions, the bomber carcasses are hauled away by scrap dealers, who pay between 18 and 30 cents a pound for the metal.

sky, and Curry felt a thundering blast. A missile had detonated just off his left wing.

The aircraft rolled right. Curry tightened his mask fittings and gulped in oxygen as he wrestled the controls in an effort to level the wings. He checked his instruments. The fuel gauges were not working. Two of the eight engines showed no signs of life.

Trying to maneuver out of the range of the missiles, Curry took the bomber to maximum speed. Then, fearing he would tear off the damaged wing, he gingerly pulled the nose up until the airspeed dropped. Finally he managed to get his craft over water.

Curry turned south toward Da Nang, the closest emergency field in South Vietnam. For 40 terrifying minutes, the crew made their way through turbulent weather. At last they were able to land. After they climbed out, they got a look at the damage. Fuel was pouring out of more than 60 holes in Aqua Two's fuselage and wing.

It turned out that the crew had just made history: they had flown the first B-52 to take a hit by a surface-to-air missile.

Curry climbed down from the Beast and wandered off among the remains of other bombers. Despite their jaunty names—*Rolling Thunder, Triple Deuce*—they seemed lifeless now.

Rolling Thunder, its back broken and its wings severed, lay on its side like a dead fish. A junk dealer had paid 18 cents a pound for it. Nearby, an older bomber painted Air

MICHAEL R. HOYT

Force gray bore a blue stripe and the sun-bleached words "Peace Is Our Profession"—the motto of the Strategic Air Command, the now-defunct division then in charge of the Air Force's bombers and missiles.

They all had personalities, these machines that had hummed to life at the flip of a switch, that had climbed into the cold, thin air toward missions that sometimes culminated in success and sometimes ended in death.

Robert Conrad eased the crane alongside the Beast. He raised the blade and swung it inches above the intended point of impact—the tail. Cowan radioed minor corrections to the crane operator in a steady, no-nonsense voice.

As Conrad engaged the drum clutch to raise the blade, Curry returned from the bomber graveyard. The crane's sound rose in pitch to a nerve-jangling whine.

The blade stopped 80 feet above the bomber. The clouds parted, and sunlight bathed mighty 666. Curry looked around, his face slack.

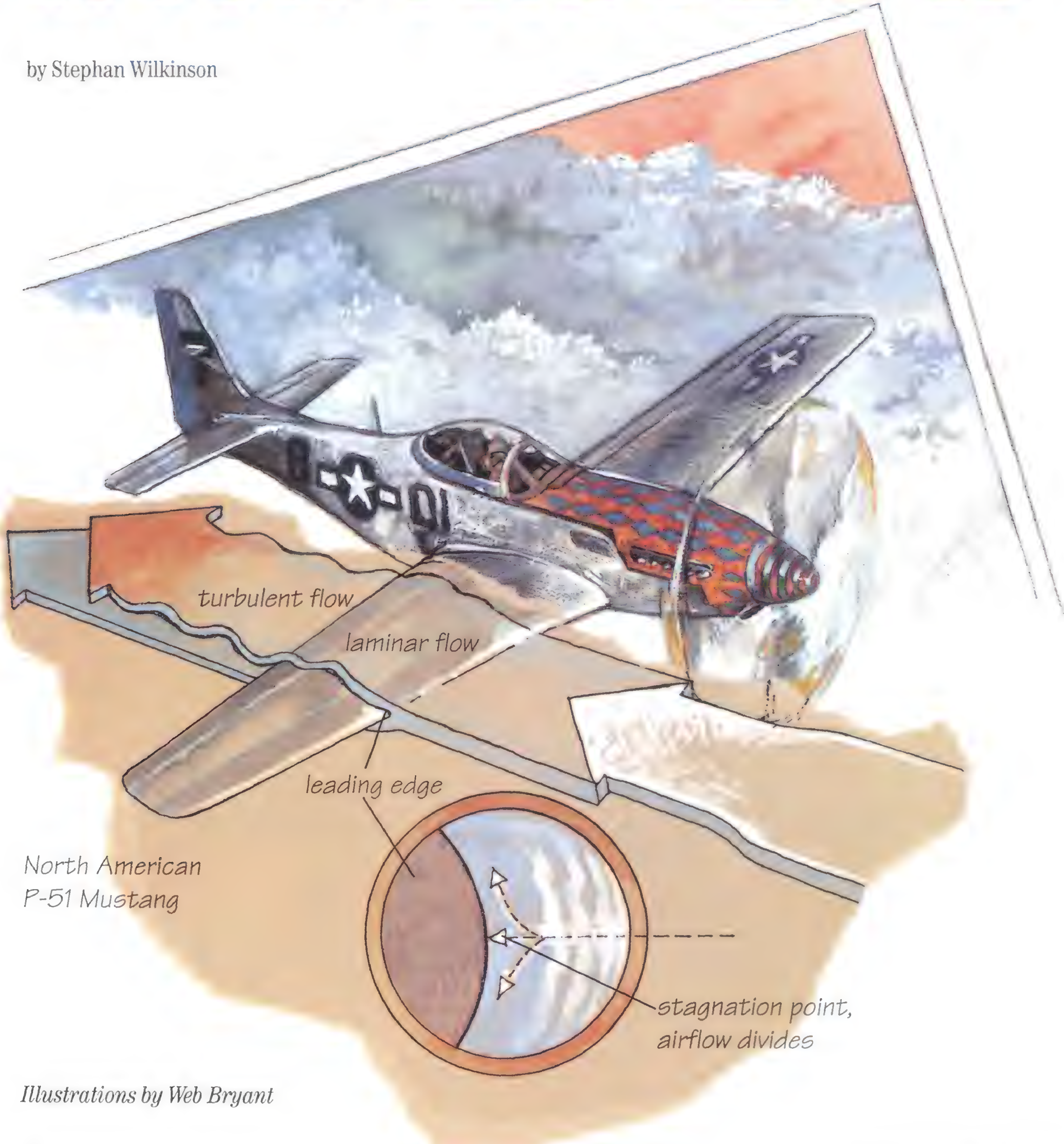
"Drop," Cowan ordered. Conrad released the drum clutch and the blade came hurtling down, landing with a *thwack* just forward of the vertical stabilizer. Curry staggered back a step. "Wow," he said in a low voice, almost a whisper. The Beast's tail shuddered, then fell to earth in a grinding, mud-splattering crash.

Though the elimination of the fleet signifies a more peaceful era of international relations, the bombers' crudely broken bodies give the desert landscape at AMARC a post-apocalyptic look.

GO WITH THE FLOW

We know how to give airplanes a performance boost that could be worth billions. So what's holding us back?

by Stephan Wilkinson



Illustrations by Web Bryant

There never was a sound barrier, and even the top of the atmosphere no longer represents so much as a snow fence. Flight faster than sound has become routine, and yesterday's research is today's reality. As we go down the list of aerospace aspirations, we've *been there, done that*, and it's time to face it: Today's flying machines are breakthrough miracles—fast, efficient, and so stubbornly reliable that airlines routinely fly a warehouse of assembled parts like the 747 around the clock for thousands of hours without so much as a second thought. Still, with all that magic parked on the ramp, there remains one bit of unfinished business—an aeronautical hurdle that has yet to be leapt.

Since the 1930s, we've been told by the popularizers of science that a technique called "laminar flow control" would enable airplanes to sip fuel and shrug off drag, slipping through the air like dolphins in a ship's bow wave. In the realm of large subsonic airliners—the mass transit of aviation—the attainment of practical laminar flow may well represent the final breakthrough to which pure aerodynamics can lead us.

With every experimental demonstration of the concept—and there have been many—we seem to reconfirm that, yup, this stuff works. If anything, the application of laminar flow control seems closer today than ever, which may be why it is the object of extensive NASA study, serious airframe-industry attention, constant university research, and considerable rivalry between the United States and Europe. It is clear to everyone that whoever first travels this last mile of aerodynamic development will gain an enormous competitive advantage. It has been estimated that a 10 percent improvement in airliner performance would increase the winner's market share by $80 billion a year.

The situation is similar to that of every physicist's fantasy: fusion power. The good news is, we're getting close. The bad news is, this has been true since...oh, about 1950.

Most of us are content to imagine that 727s, MD-11s, and A320s already slip through the air like dolphins. They leave a trail of turbulence in their wake, but they seem to cleave the atmosphere quite nicely. In fact the turbulence begins long before the airplane has slipped past the parcel of air within which, instant by instant, it is traveling.

"Every molecule of air takes the path of least resistance," explains aerodynamicist John Roncz, designer of wings for such airplanes as the globe-circling Voyager (see "Wing Man," Dec. 1990/Jan. 1991). "Imagine you're an air molecule, sitting there floating along in space, and an airplane comes toward you. Unless you're pushed out of the way by the fuselage, you end up flowing either above or below the wing, and there's a single molecule of difference between those two paths. There's a traffic cop at the leading edge, called the stagnation point, and he decides who goes over the top of the wing and who goes under the bottom." The molecule that takes the low road, under the wing, need only go with the flow. High pressure helps to hold it against the airfoil as it slides aft, just like the air that presses against your palm when you stick your hand out the car window and angle it slightly to make a "wing."

But the little guy that the stagnation cop sends over the top of the wing has a harder job: there's low pressure up there trying to tear the air molecule away from the wing surface and set it to bouncing and burbling. A laminar flow air molecule travels like a surfer sliding smoothly down the crest of a wave, always an instant ahead of disaster. A turbulent molecule is a wiped-out dude plunging toward the beach ass over teakettle.

So what is laminar flow? Keep in mind that "laminar" means "layered." Roncz explains that if you pushed a laminar airfoil through a pile of snow, the airfoil would "simply shoulder the snow aside without mixing or agitating the different layers of snow. That's laminar flow." Turbulent flow, on the other hand, would be the equivalent of pushing a rough board through the same snowdrift. Or, more to the point, a bumpy, bug-splattered, paint-chipped, rivet-buckled, walked-on-by-mechanics ordinary wing. The layers of snow would indeed be shoved aside, and the equivalent of lift would be produced. But the snow nearest to the wing's surface would be tossed and roiled by its passage. That's turbulence.

Actually, there is no such thing as absolutely pure laminar flow, for there is always a very thin and relatively stagnant "boundary layer" of air between the skin of an airplane and the free-stream air surrounding it. Because an airplane's skin, no matter how smooth, has microscopic irregularities that tickle the air going past it at high speed, the closest molecules stumble and slow, caught by the skin's snags. Those molecules impart their confusion to some in the next outward layer, and those to the next.... Imagine a roaring river at flood stage; within an inch of its banks, the water barely moves, though it burbles and twists. Those banks are the equivalent of an airplane's wing experiencing non-laminar flow.

Ideally, the boundary layer is only an inch thick at most, and the effect dissipates quickly away from the wing's surface. But if you could somehow eliminate most of that nearby layer of air, say by sucking it away with a million tiny vacuum cleaners embedded in the upper wing, you'd eliminate a lot of the wing's turbulent flow. In fact, this is what engineers refer to as "active laminar flow control"—any system that deals with the turbulent layer on the wing's surface.

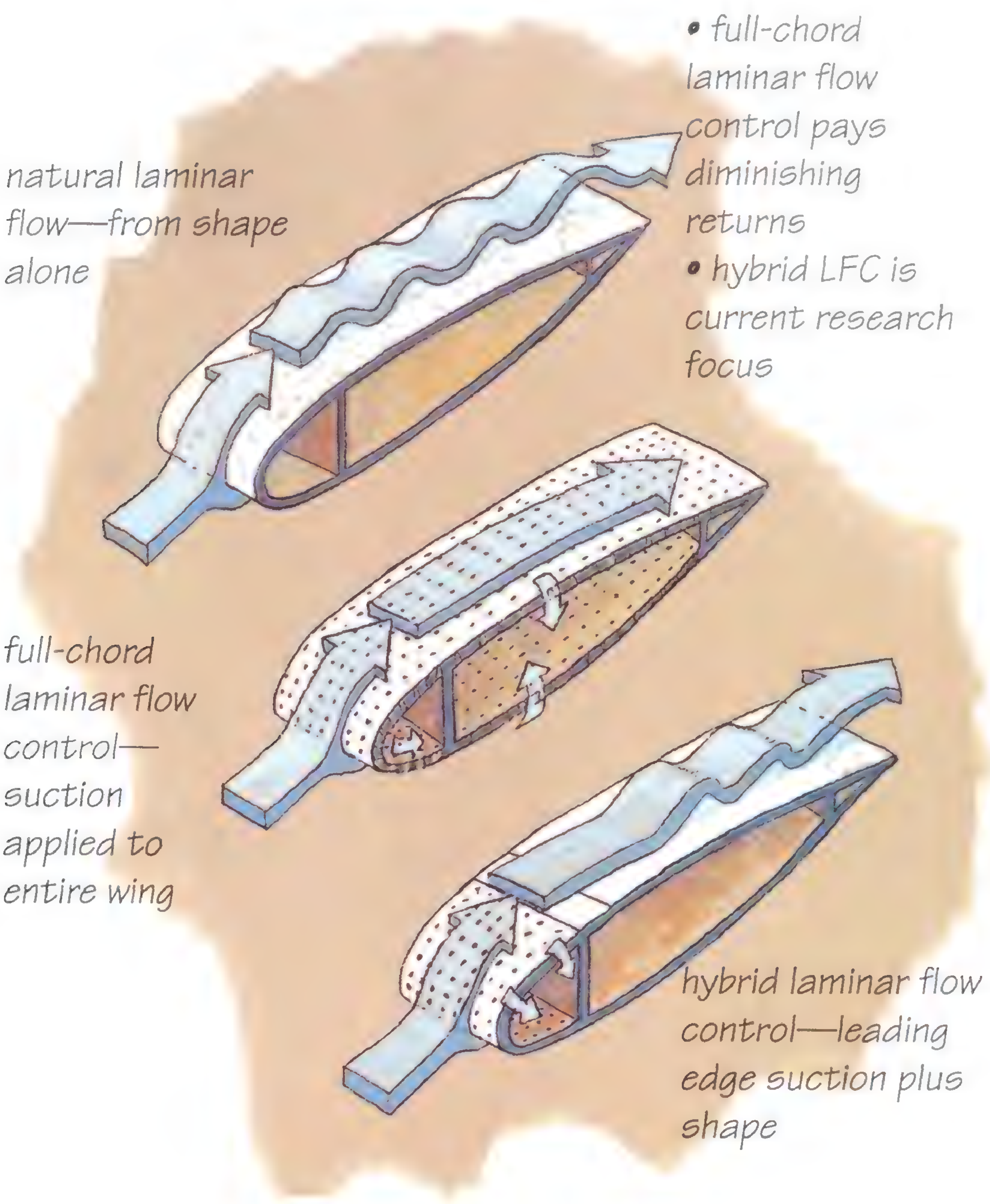
Turbulence creates drag. It'll also make lift, unless the turbulence gets so extreme the wing stalls. The airflow over an ordinary wing remains laminar for only the first 20 percent or so of chord (the distance from the wing's leading edge to its trailing edge). But the greater the turbulence, the greater the drag. And the greater the drag, the greater the amount of fuel that has to be burned to achieve a given speed. Or, to put it another way, the shorter the distance the airplane can fly on a given amount of fuel. Get rid of that drag and the airplane will fly either farther or faster—or it can be built with a smaller, lighter wing and do both.

Since airlines worry about the weight of fuselage paint, forks, and in-flight magazines, doesn't this sound like something that should get their attention? Improving a single new aircraft's performance by 10 percent could save $10 million per year. Yet so far, the only production airplanes that have taken advantage of recent advances in laminar flow technology are a few lightplanes and business jets.

Laminar flow control is the object of considerable controversy, with exasperated scientists claiming that it could be used to achieve marvelous gains in performance and fuel economy if only the airframe manufacturers had the guts to build it, while aeronautical engineers respond with a list of showstoppers that threaten to send effective, practical laminar flow control straight back to the pages of *Popular Mechanics*.

"We need to listen to the airframers when they raise these issues," admits Fayette S. Collier, the head of NASA's Laminar Flow Control Project office at Langley Research Center in Virginia. "If you add a brand-new system to an airplane, the challenge is making everything work together. The airframers are the guys who are saying, 'Yeah, you've got a great system, but how do we integrate it with anti-ice, with pressurization; how do we maintain it, de-ice it, keep dirt and bugs out of it?' "

On a small part of a Boeing 757 wing, NASA has developed and flight-proven a "hybrid laminar flow control system"—a combination of active, mechanically aided laminar flow and natural laminar flow produced solely by the shape of the airfoil. The engineers are confident that a hybrid wing could net a 10- to 15-percent gain in fuel economy if an airplane were designed around it. (Unfortunately, the system can't simply be tacked onto existing airframes for anything but limited testing purposes.) If a brand-new airframe were developed and such efforts were extended to the design of engine nacelles and pylons, even greater gains might be possible.



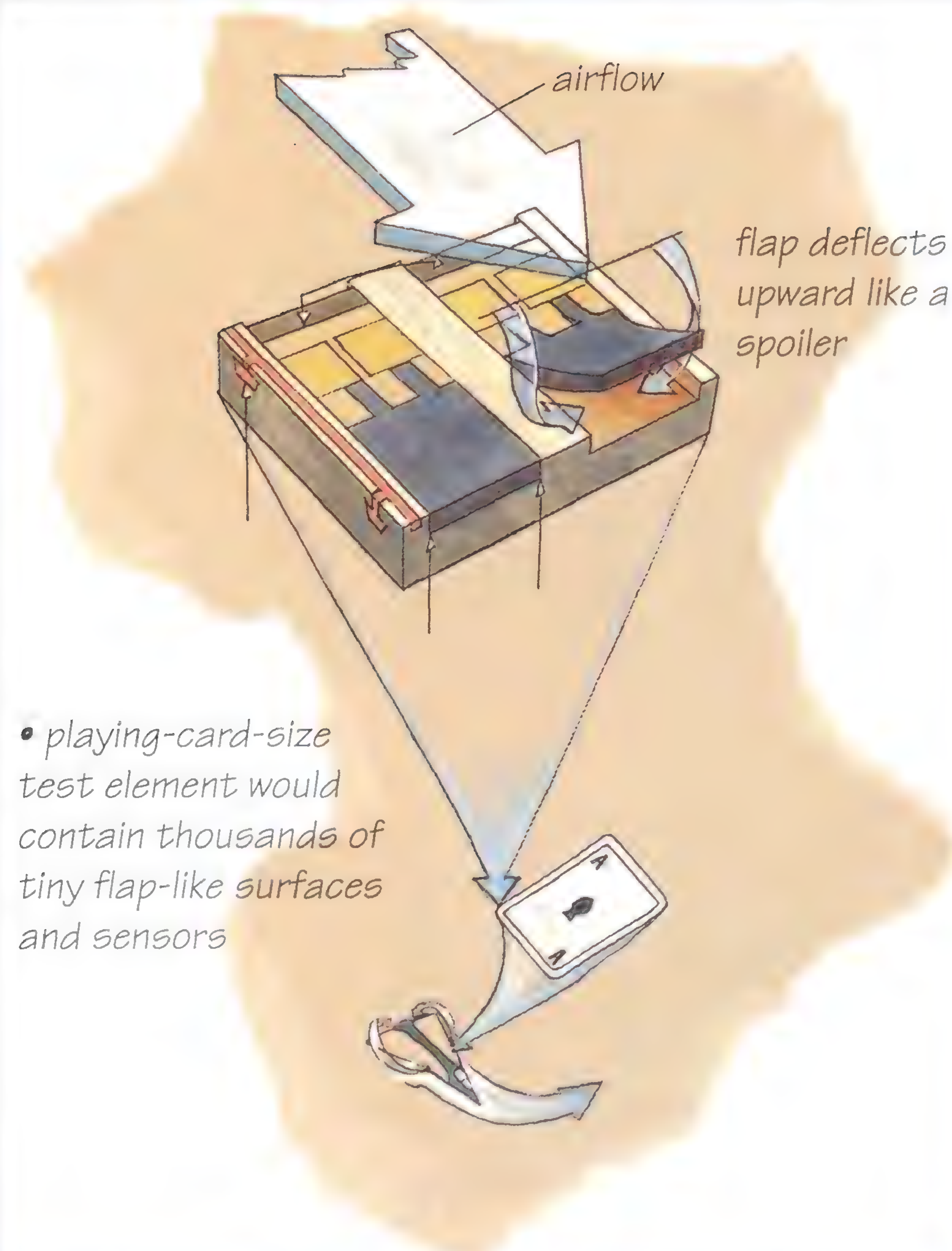
"Laminar nacelles would result in another one percent reduction in fuel consumption," says Collier. "That may sound small, but it's a greater fuel saving than future advances in engine technology are expected to bring."

But the key phrase is "brand-new airframe." According to Richard Gritta, a specialist in airline economics at the University of Portland in Oregon, "A 10 percent savings would certainly be worthwhile, since fuel costs typically are about a third of an airline's direct operating costs." (Others claim 17 to 20 percent is a more reasonable range.) "I've known airlines to strip their paint off to get less drag and eliminate 500 pounds of extra weight," Gritta continues. "Right now there are a lot of airlines that have very high costs because they're flying inefficient aircraft. Why? Why do some people drive old cars around for years? Because they can't afford a new one. The airlines simply don't have the financing to buy efficient new aircraft."

The National Advisory Committee for Aeronautics, NASA's predecessor, had done primitive boundary-layer research as early as 1926, but true laminar flow efforts began in Germany in the 1930s. The NACA brought its early efforts to practical fruition just before World War II, when engineers put an enormous wooden cuff on the wing of a Douglas B-18, a pigeon-chested bomber version of the twin-engine DC-2 airliner. The cuff was sanded, worried, and polished to within a near-flawless two-thousandths of an inch, and it worked remarkably well.

Not for another 40 years would NASA do better, and it took a polished-fiberglass cuff on an F-111 swing-wing fighter-bomber to do it. Two early post-war experiments, one by the British using a Hawker Hurricane and the other by the Americans with a Bell P-63 Kingcobra fighter, also achieved surprisingly good numbers. But both airplanes had mirror-smooth natural laminar flow wing sections that would have been utterly unattainable in any kind of mass production.

The North American P-51 Mustang was widely said to have a "laminar flow airfoil," an attribute that made little practical difference. "When it came off the



Small but Very Smart

"Smart" is an engineering buzzword for the '90s: there are smart cars, smart highways, smart bombs, smart TVs, and, if a group of University of California at Los Angeles and Cal Tech researchers can work it out, smart wings.

These scientists and engineers have developed a "microelectromechanical system" that, instant by nano-instant, alters the airflow over a wing to maintain laminar flow. Whenever microscopic sensors detect the changes in airflow that foretell an incipient burble, minute tabs that function as tiny spoilers bend upward into the airflow to create counter-burbles that cancel out the boundary layer separation.

Microelectromechanical systems—let's henceforth revert to the official acronym MEMS—include devices (flaplets, in this case) so small that thousands of them can be built into microchips that also house the controlling sensors as well as the actuators that activate the surfaces themselves. (We're talking *way* tiny here: Think of sequins too small for a Barbie doll's cocktail dress. The UCLA/Cal Tech team foresees important uses for a version of the system implanted in the human body to detect and correct the adverse blood flow that can lead to arterial clotting, among other things.)

If you have doubts about systems nearly as delicate as butterfly wings surviving on an airliner in today's air transportation environment, it helps to understand that the research project is largely driven by the needs of future military aircraft. For stealthy airplanes, MEMS arrays that maintain laminar flow could also be used as substitutes for conventional movable control surfaces, which can create radar signatures when they're deflected. Deflect a bunch of MEMS on one wing or the other, say, and considerable lift asymmetry can be created, literally invisibly, rolling the airplane just the way an aileron would.

production line it probably was laminar over maybe half the chord, but there was little time thereafter when that was true," says Fay Collier, pointing out the effects of wear and tear. "Still, I've heard pilots say they could feel the difference, either in speed or in climbout capability, between P-51 wings that were laminar and those that had ceased to be."

In 1947 the British built the most extensive laminar flow flight-test aircraft yet attempted: an odd swept-wing, twin-jet flying wing called the Armstrong Whitworth A.W.52, a half-size prototype of what was intended to be a tailless airliner.

Despite an airfoil that had performed excellently in the wind tunnel, the A.W.52 was a failure. The sweep of the wing had added confounding elements to the laminar flow equation. For one thing, the air over a swept wing doesn't flow straight aft but creeps strongly sideways—"spanwise flow"—toward the wingtips. And spanwise flow seems to disturb any laminarity that is achieved. "Aerodynamicists had to go through a whole new learning process when swept wings came in," explains Collier, "because now they were dealing with cross-flow disturbances as well as chordwise disturbances."

Figuring that natural laminar flow produced entirely by the shape and smoothness of the wing was a hopeless phantasm, the British initiated the first active laminar flow control project. In 1955 three de Havilland Vampire jet fighters were fitted with several kinds of porous wing surfaces through which the turbulent air closest to the wing was vacuumed away to create laminar flow. NASA was at the same time trying a similar strategy on a Lockheed F-94 interceptor, another straight-wing jet.

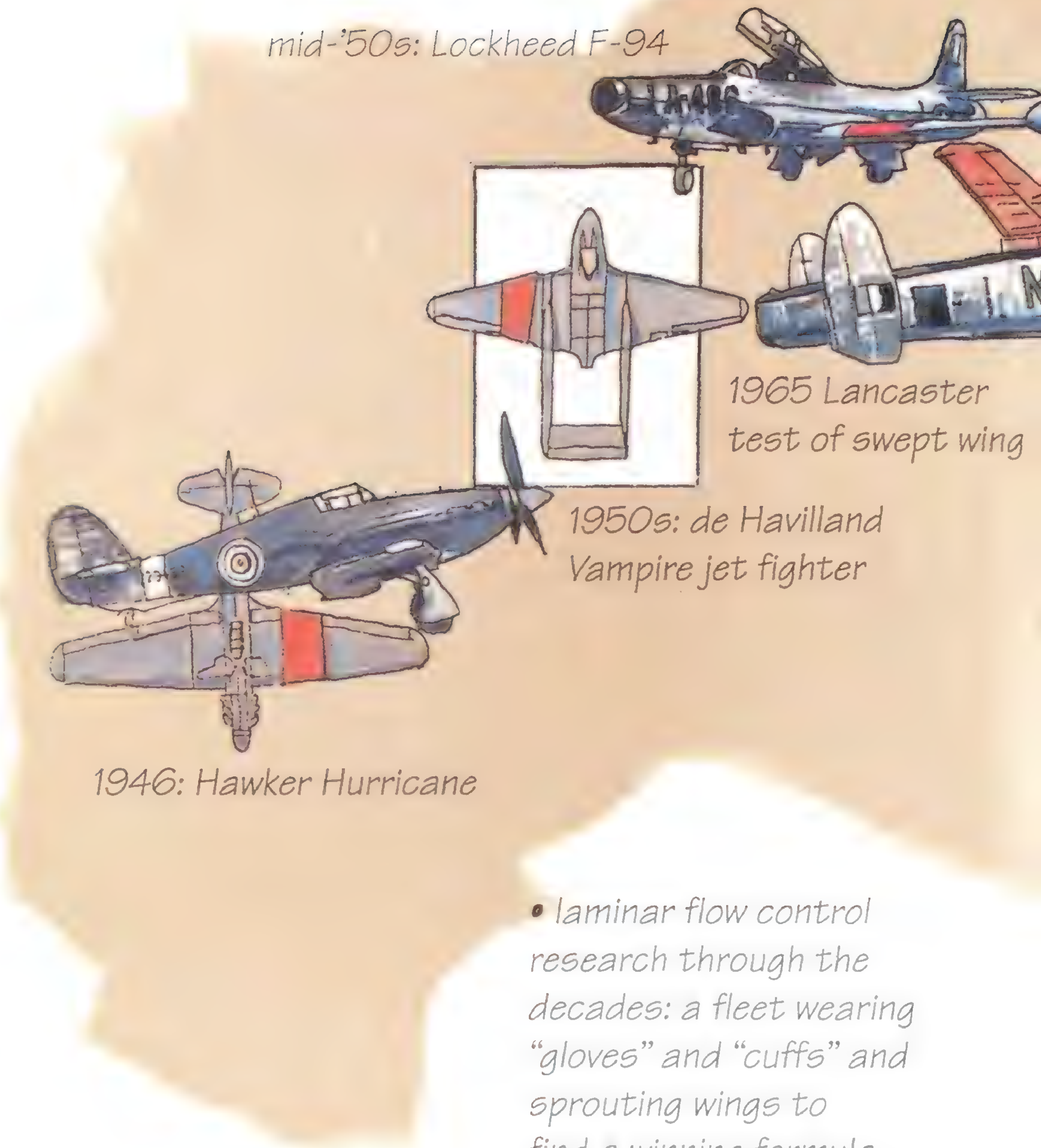
Both tests worked, after a fashion, but the airplanes were encumbered with complex extra systems, requiring considerable power to run the suction pumps. The tiny holes in the Vampires' wings—which actually weren't all that tiny—set up their own airflow disturbances and weakened the wing skin enough to cause it to deform in flight.

But by then, the Boeing B-47 had shown that future large subsonic jets would have to have swept wings. It had already become obvious that the only airplanes that could retain unswept

wings would be those so small and slow that active laminar flow control wouldn't be worth the effort. The Vampires and F-94s were pterodactyls, not much better than 1940s piston-engine designs with jets.

In 1966, Northrop and the U.S. Air Force put together the biggest laminar flow project ever attempted and built two of the largest X-planes ever flown: the X-21As. The experimental twin-jets started life as weather-reconaissance Douglas WB-66 jets, electronic warfare versions of which saw service over Vietnam. Under a distinctive humped back, each X-21 sported a swept laminar flow control wing lined with thousands of spanwise razor-thin slits that were in turn perforated with over 815,000 minuscule holes, each of which sucked away turbulent air into a vast internal network of nearly 68,000 ducts, all leading to a pair of high-pressure pumps under the wings. The B-66's main engines were moved from their underwing pylons to aft shoulder mounts like those on a typical business jet.

The X-21s were meant to prove not only that active laminar flow was achievable but that such a system could be manufactured, maintained, and operated in an everyday environment. "The X-21As proved conclusively that…[laminar flow control] is both effective and viable," experimental-aircraft authority Jay Miller writes in his book *The X-Planes*. "However, they also demonstrated that LFC incurred certain maintenance penalties that were not easily overcome…[and] that production technology for manufacturing LFC surfaces and related components was…prohibitively expensive for all but experimental aircraft."



• laminar flow control research through the decades: a fleet wearing "gloves" and "cuffs" and sprouting wings to find a winning formula

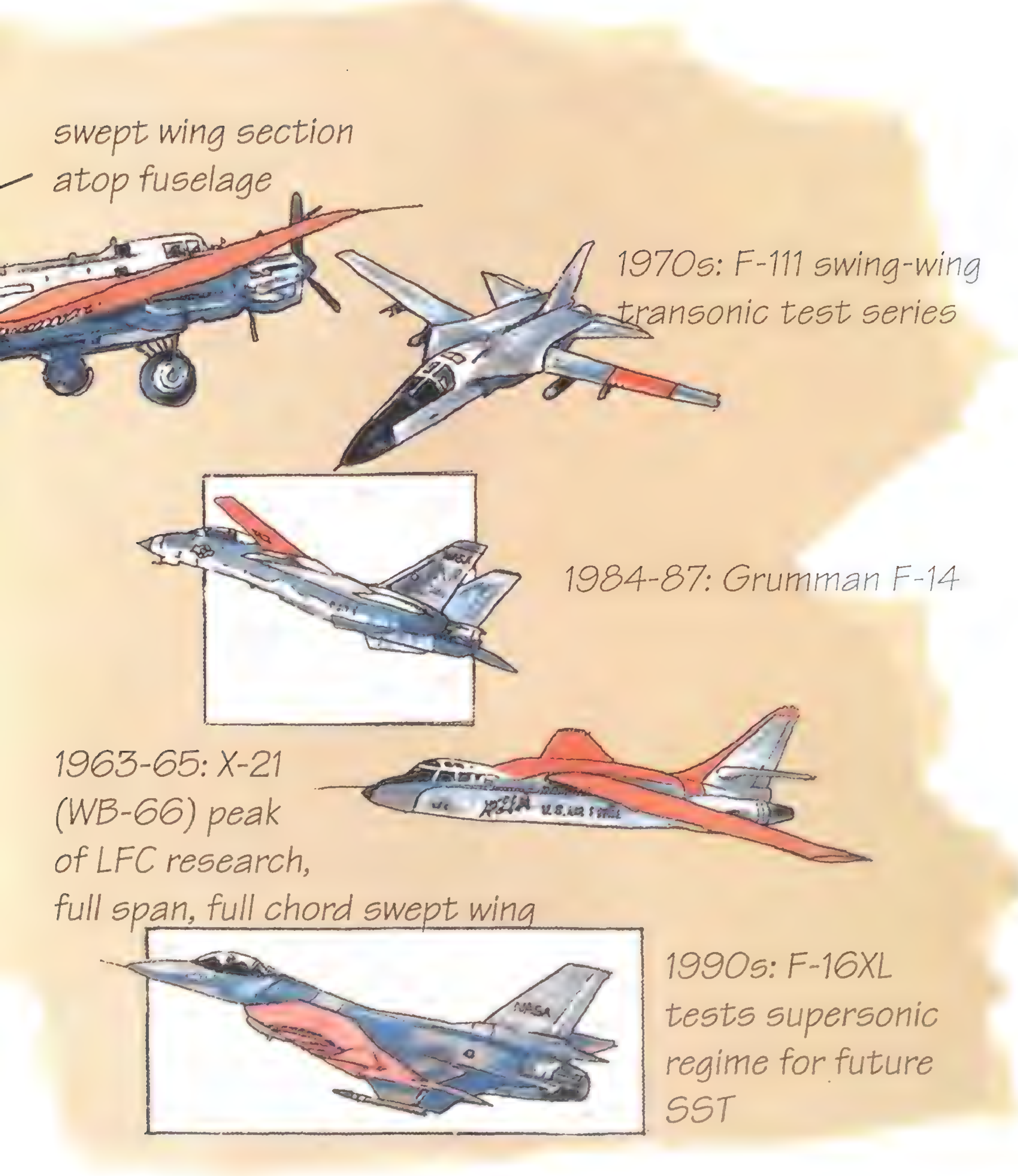
NASA's laminar flow efforts were reinvigorated in the 1970s, when 10-cent-a-gallon jet fuel became a fond memory. (Last year, jet fuel cost around 65 cents a gallon.) Forty years of research and flight testing had proved that active laminar flow control worked. The X-21As had demonstrated that it was possible for pumps to suck away so much turbulent air that nearly three-quarters of the wing's flow was cleanly laminar.

But the research had also shown that going beyond a certain point produces diminishing returns. A modern subsonic-transport airfoil provides serious lift with the forward 60 to 65 percent of its chord—the "pressure recovery" portion of the wing. Aft of that, the wing provides structure rather than lift, and it is merely along for the ride—a framework to hold flaps, ailerons, and stiffening spars. Beyond 65 percent, Fay Collier points out, "the wing no longer contributes to an improvement in drag, in terms of laminar flow. Though that's what they tried to do with the F-94 and the X-21A research—full-chord laminar flow—it simply doesn't pay.

"What NASA is now trying to do," says Collier, "is provide active laminar flow for the leading edge and the first 15 percent of chord, then get a resulting natural laminar flow from the area from 15 percent of chord to 50, 60 or even 70 percent, depending on how aggressive you want to be in your airfoil design." And the hybrid wing is producing those kinds of numbers.

The X-21A program had demonstrated that active laminar flow could be achieved using a hand-built wing that required constant maintenance—much of it devoted to keeping the pinholes from clogging with dust, dirt, and bugs—and enough power on board to run the hungry pumps. Active laminar flow control seemed to be a laboratory oddity with no hope of practical application. Unfortunately, that may be nearly as true today as it was in 1966.

The size and shape of the pinholes—and tuning the exact amount of suction applied through them—are the keys to the success or failure of any active laminar flow control system. In the 1940s and '50s, the trick was drilling the holes small enough or finding a porous wing material strong enough. In the '60s and '70s, the holes got smaller and more



precise, but the problem became one of keeping them from clogging with dust and dirt.

In the 1980s, electron-beam drilling solved the pinhole-precision problem while introducing a refinement that seems to have mitigated the clogging problem. The holes can be drilled with an inverse taper—they get bigger as they go into the wing—so anything small enough to get into the hole on the wing's exterior surface flows through the rest of the system.

But the amount of suction applied to different parts of the wing has to be metered precisely: Too little won't achieve laminar flow, and too much will make the air molecules trying to get through the tiny holes jam up like Tokyo subway commuters. What engineers want are molecules as orderly as the Dallas Cowboys trotting into the clubhouse tunnel at halftime.

Another potential showstopper is the desirability of having some kind of anti-ice protection on the leading edges of airliner wings. Designs and operating techniques differ, but many jets have wings with leading edges heated by air bled from inside the engines whenever there's a threat of serious ice. (Some recent crashes have been blamed on snow and ice that accumulated on wings while the airliners were parked on the ground, but that's an entirely different problem.)

"If you take a perforated leading edge with all its plumbing, as you'd have with a suction system, you don't have any room for a hot-air ice protection system," points out Frank Lynch, McDonnell Douglas' laminar flow expert. No ivory-tower guy, Lynch is the leader of the group that designed the DC-10. He has prowled ramps, flown routes, dealt with the Federal Aviation Administration, and experienced firsthand what is involved in making an airliner truly operational. "People have been talking about blowing hot air back out through the suction system in low-speed conditions where you don't need laminar flow," he says, "but this can create significant disturbances, and you're worried it can have a major impact on the stall speed of the airplane."

What about slowly bleeding de-icing fluid out of a small spray bar of some sort embedded in the leading edge, so that it would constantly coat the wing and prevent ice buildup? Such a "weeping wing" system has been used successfully on smaller airplanes and is currently the focus of European hopes. "I did a study on that," Lynch says, "and concluded that in order to be able to handle worst-case situations, you needed something like 10,000 gallons of fluid for a modest-size transport aircraft. And even if I'm wrong by an order of magnitude, airlines aren't going to want to carry that much extra stuff around everywhere."

Public perceptions matter as well. "We know the weeping-wing system works," says Collier, "but what about passengers looking out the windows and wondering why the wing is 'leaking'? So we're looking for a more publicly acceptable solution—things like permanent coatings. Teflon was explored in the early 1980s, and we're building on that: What's viable, what's out there?"

Perhaps the biggest showstopper, however, is spelled out by John Roncz, a big fan of natural laminar flow as opposed to active systems. "The hard nut to crack is that you have to assume that eventually the suction system will fail, okay? You have to design an airfoil that can live without the active LFC, to design so that when it goes away, you're still safe. And that's going to limit you, because you'd really like to design an airfoil that depends on the laminar flow. That's how you get the really nice drag reductions."

Laminar flow enthusiasts talk earnestly about such drag reductions enabling a wing to be made up to a third smaller and lighter than a conventional wing, thus requiring less powerful, lighter, and more fuel-efficient engines, thus leaving more payload for passengers

or freight—a round of benefits that all accrue from pinholes and pumps. But just as FAA officials say "Show me what you're going to do with your two-engine airliner when one engine stops over the middle of the Atlantic," they will demand proof that two normal pilots can handle matters when a loaded wide-body suddenly loses a lot of lift when the pump or a duct fails, as will inevitably happen.

"No airline is going to buy an airplane on the assumption that a system will always work," says Frank Lynch of McDonnell Douglas. "Sure, one of the economic advantages of LFC is that you might be able to downsize the wing because of reduced drag, which in turn downsizes the vehicle, which downsizes the engines, which reduces emissions and so forth. However, if you can't count on the system 100 percent of the time, your successful long-range airplane turns into a medium-range airplane. And the airlines won't take that."

The flow of air over a large transport is a complex affair with many troublesome components besides the wings—fuselage, tail, engine pylons, nacelles. Much of the flow around the airplane is transonic, some of it even supersonic. A single insect swatted by the leading edge of a laminar flow wing can disrupt the flow aft of its last resting place, creating an ever-widening wedge of turbulence. A laminar flow airliner taking off into a typical New Orleans swarm of lovebugs during mating season might as well have boards for wings unless it has some means of preventing bug splats.

Even the rumble of an engine can disrupt laminar flow, and when a large airplane rolls into a turn, the eddies, wakes, and vortices cast off by parts of the structure can make a mockery of the most carefully planned laminar flow profile. "One of the big problems with laminar flow control is that unpredictable disturbances will occur," says Joseph Klewicki of the University of Utah, chief investigator in a National Science Foundation-funded project on laminar flow. "Once roughness or external acoustic disturbances are introduced, you can get what are called 'bypass transitions' that undermine any sort of flow control strategy."

"You can go design a wing and its interface with the fuselage with exactly the kind of pressure distributions you want for laminar flow," says Frank Lynch. "Then you go and install the engine nacelles and pylons, and it modifies everything greatly. You can take what was a very nice flow region inboard of a nacelle and end up with a very strong shock wave. The area outboard of the nacelle, which is where NASA's 757 experiment was done—the nacelle effect is actually favorable in that area. You might say that work was close to a slam-dunk."

"Leading edge contamination leads to one form of bypass transition," Klewicki points out. "Surface roughness is another mechanism. It's good that NASA is achieving 10 percent drag reduction, but were these freshly cleaned wings? I'm nervous that the system wouldn't have long-term reliability, and I suspect that's why airframe companies aren't buying into it yet: they may think the tests were 'too clean' compared to the conditions under which airplanes actually operate."

NASA operated an experimental hybrid laminar flow control system on a Lockheed JetStar for a year in "simulated airline service," meaning that the airplane was parked outdoors, serviced routinely, flown in bad weather and good, in ice and rain and buggy heat. "It worked fine," says Fay Collier. "But let's not fool ourselves. We need to know what happens to these systems in thousands of hours of service, not hundreds, over the course of years. That question has not been answered yet."

Frank Lynch would agree. "It's very educational to walk the ramp at a major airport, see the environment these airplanes operate in. You run into hail occasionally, for example, and the criteria for replacing a hail-damaged laminar leading edge are going to be quite a bit more [stringent] than they are for a turbulent-wing airplane."

NASA feels that one solution to the

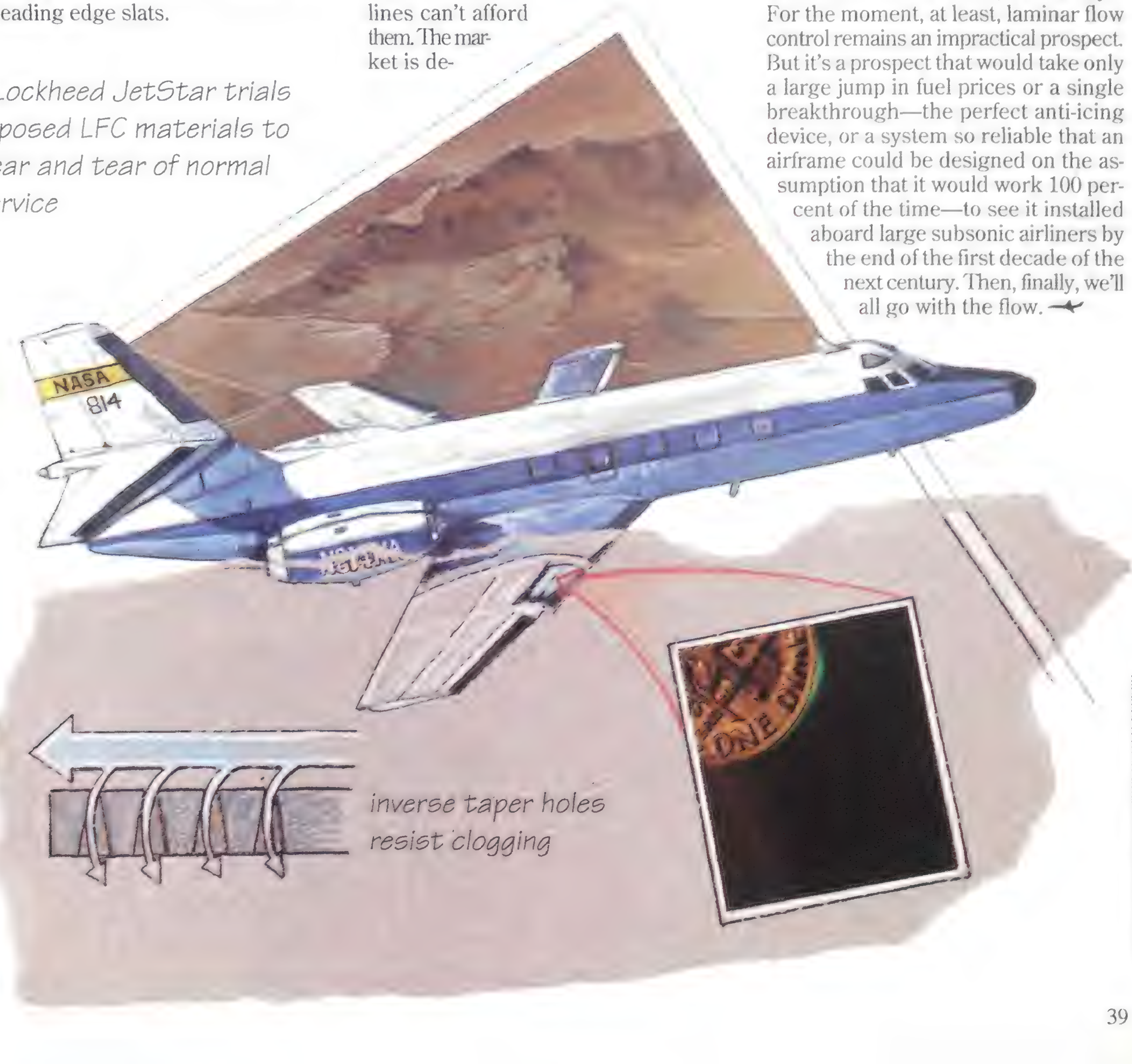
bug contamination problem is the use of Krueger flaps instead of leading edge slats. Both devices are used to increase the airflow over the wing at low speeds. In cruise flight, ordinary slats retract to become the leading edge, putting contamination right where it has the worst effect. The Krueger flaps would take the bug hits that are inevitable during departures and approaches and then fold into the lower surface of the wing for climb and cruise.

Krueger flaps, however, come with their own set of problems: Unlike modern autoslats, they can't be modulated—trimmed and adjusted—to tailor the performance of different parts of a wing. It is difficult to protect them against ice when they're extended. And their takeoff performance can't match that of leading edge slats.

Only a fool would say of any technological advance, "It'll never happen." Certainly laminar flow control is an advance whose time will come, though it seems equally obvious that it isn't here yet. There's a gap between what is attainable and what is doable. Detroit could produce 100-mile-per-gallon sedans tomorrow, 200-mpg cars next week. Could individuals afford them, would the market want them, would they be safe on today's roads? No, no, and no, given the cost of the technology, materials, and manufacturing necessary; the price of fuel today and in the foreseeable future; and the demands of the marketplace as it exists.

Much the same could be said of large subsonic airliners with laminar flow control. Airlines can't afford them. The market is demanding simpler, cheaper, and more easily maintained aircraft, not new systems with unknown maintenance needs. And fuel isn't so expensive that a 10 percent saving is a burning necessity. "The issue is not drag reduction, it's cost reduction," says Mark Drela, an aerodynamicist at the Massachusetts Institute of Technology. "LFC is achievable technically, but the big question is: Does it pay? Can the additional acquisition cost, maintenance cost, and lower dispatch reliability be more than offset by decreased fuel costs? If not, then LFC doesn't make any sense.

"The ball is out of the aerodynamicists' court, and now it's up to the mechanical engineers, operations analysts, and airline economists to decide whether or not LFC makes sense," Drela says. For the moment, at least, laminar flow control remains an impractical prospect. But it's a prospect that would take only a large jump in fuel prices or a single breakthrough—the perfect anti-icing device, or a system so reliable that an airframe could be designed on the assumption that it would work 100 percent of the time—to see it installed aboard large subsonic airliners by the end of the first decade of the next century. Then, finally, we'll all go with the flow.



• Lockheed JetStar trials exposed LFC materials to wear and tear of normal service

TONY LANDIS AND DENNIS TAYLOR, NASA DRYDEN

Radio astronomers breathe new life into an old telescope by making an improved map of our galaxy.

by Donald Goldsmith

Near Dwingeloo in the northern Netherlands, a parabolic metal dish 25 meters in diameter rises above a landscape as flat as a soccer field. When Queen Juliana dedicated it in 1956, this antenna was the world's largest steerable radio telescope, a tribute to Dutch leadership in the field of radio astronomy and an instrument to which astronomers from around the world came to observe the cosmos. By the late 1980s, the telescope's glory days seemed over. At best it would be preserved as a relic, like the giant trees in the nature reserve where it was built. At worst it would be scrapped. But thanks to the efforts of two astronomers who found a use for the old telescope, the Dwingeloo antenna is still making a contribution by gathering data for new and better maps of the Milky Way galaxy.

The discipline of radio astronomy had been created in the United States during the 1930s, through observations of "cosmic radio static" made by an engineer, Karl Jansky, and an amateur astronomer and ham radio operator, Grote Reber. During World War II most scientists were busy at military tasks and research in the field slowed. The situation was especially difficult in Nazi-occupied Holland. Yet even in these trying times a group of astronomers led by the versatile scientist Jan Oort managed to hold meetings to discuss their scientific true loves. High on the astronomers' list was radio astronomy.

In 1944 a Dutch astronomy student, Hendrick van de Hulst (later Oort's col-

CAROLINE SHEEN

Returned to an active life in the 1980s, the radio telescope at Dwingeloo now listens to the faint emissions from atoms scattered across our galaxy.

Mapping

the Milky Way

LEIDEN OBSERVATORY (2)

The pioneering work of Jan Oort (inset) helped place the Netherlands' Leiden University at the forefront of radio astronomy.

league at the University of Leiden for 40 years), predicted that interstellar hydrogen atoms—the most abundant of all the atoms that float among the stars—should emit radio waves. Van de Hulst predicted the hydrogen emission would be at a frequency of 1,420 megahertz (which would mean a wavelength of 21 centimeters). Because hydrogen atoms do not emit visible light, the opportunity to find interstellar hydrogen by observing radio waves excited astronomers as a new way to observe the cosmos, mainly because such emissions would not be absorbed by interstellar dust, as visible light is. The dust cloaks the stars from sight, but it can't stop the material of stars yet to be born from being observed (see "Tuning in to the Galaxy" and "The Hydrogen Show," right).

A laboratory fire in 1951 prevented Dutch astronomers from becoming the first to observe radio waves emitted by interstellar hydrogen atoms. (The honor went to two Harvard physicists, Harold Ewen and Edward Purcell.) Undaunted, the astronomers of Holland plunged wholeheartedly into radio astronomy, and under Oort's leadership they devoted a significant portion of the Netherlands' astronomy budget to the new field. Using a 7.5-meter radar antenna that the German army had left behind, they measured hydrogen emission by scanning the entire sky visible from Holland during the course of a year. This early survey of cosmic radio waves helped put the Dutch at the front of the radio astronomy effort.

During the late 1950s, astronomers used the Dwingeloo telescope to create the then-best map of the distribution of interstellar hydrogen atoms in the Milky Way. Once the astronomers had calculated the average radio emission that each atom would produce, their measurements of signal strength revealed the number of hydrogen atoms along each line of sight. And since hydrogen is by far the most abundant atom in interstellar space, these distribution measurements provided an excellent determination of the total number of atoms in each direction. In addition, the determination of the Doppler shift in the emission provided the distance to the hydrogen. All the elements were in place to make the first map of the Milky Way (see "Measurement Tools," right).

During the 1950s and 1960s, Dutch research in radio astronomy attracted young astronomers from all over the world. Among them was a young Swarthmore College graduate named Butler Burton, who enrolled at the University of Leiden in 1962, received his doctorate a few years later, and, after stints at the United States' National Radio Astronomy Observatory in Green Bank, West Virginia, and the University of Minnesota, became a member of both the Leiden faculty and the university

Tuning in to the Galaxy

Visible light and radio waves are forms of electromagnetic radiation. Both can be characterized by wavelength—the distance between energy crests in successive cycles—and frequency—the number of crests that pass a point in space per second. Frequency is measured in millions of cycles per second, or megahertz.

Like an ordinary visible-light telescope, a radio telescope studies distant objects by collecting their electromagnetic emissions. The difficulty with radio astronomy is that radio wavelengths are much longer than those of visible light—up to yards in length, rather than the millionths of an inch in which visible light is measured. A telescope's resolution—its ability to discern detail—is a function of the relationship between wavelength and the size of the collector. Longer wavelengths need larger collecting devices to provide adequate resolution, which is why radio telescopes have such large dishes. As the radio waves arrive at the telescope, they strike the parabolic collecting surface and are reflected to a single focal point at its center. The signals from space are extremely weak and must be greatly amplified.

The accuracy of any map of radio emissions depends not only on the antenna's size but also on the receiver's *velocity* resolution—that is, its ability to differentiate among the different frequencies being detected.

ROGER RESSMEYER/STARLIGHT

KITT PEAK NATIONAL OBSERVATORY

The Milky Way galaxy is shaped like a spiral, much like this galaxy from the constellation of Pisces (below left). Our solar system resides in the Milky Way's suburbs, on the outskirts of one of the spiral arms. From this vantage point, the view toward the galactic center (large photo) is ablaze with stars, but much is obscured by dust. By using radio telescopes (below) to measure the emission from neutral hydrogen atoms, astronomers have gained a better understanding of our galaxy's structure.

The Hydrogen Show

Hydrogen is the simplest atom, consisting of a positively charged proton with a single negatively charged electron orbiting it, giving the atom no net charge and making it "neutral." The electron can spin about its axis relative to the proton's spin in one of two directions. When an electron changes its spin from the higher energy direction to the lower, it emits radio energy at a frequency of 1,420 megahertz (in comparison, the radio band assigned to FM broadcasting runs from 88 to 108 megahertz). A hydrogen atom alone in space has a probability of spontaneously changing its spin direction only once every 11 million years. Fortunately for astronomers, encounters between hydrogen atoms in space increase the probability of a change to once every 300 to 400 years. Even at that low rate, the number of hydrogen atoms along a single line of sight through interstellar space is large enough to permit Earthbound radio telescopes to "hear" the cumulative emission of the trillions upon trillions of atoms.

Measurement Tools

Thanks largely to work done by Jan Oort, astronomers with radio telescopes have been able to determine the distances to hydrogen atoms floating in interstellar space. During the 1920s and 1930s, Oort analyzed the motions of the stars in the Milky Way and deduced that the entire Milky Way galaxy—the collection of several hundred billion stars that contains our solar system in its outer suburbs—is rotating like a gigantic pinwheel.

Oort showed that each of the stars in our galaxy orbits the galactic center, typically in a nearly circular path. Our sun, for instance, which lies 30,000 light-years from the center, maintains that distance as it circles the center, taking about 240 million years for each trip. But Oort found something else: Stars closer to the center take less time to complete each orbit than those farther out (unlike a spinning phonograph record, where points on the outside and inside of the disk rotate at different speeds yet take the same amount of time to make a single rotation). Astronomers use the term "differential rotation" to describe how different parts of the Milky Way orbit at different speeds around the galactic center.

Astronomers can measure how rapidly a body is moving relative to us by observing the Doppler effect, the phenomenon in which relative motion will change the wavelengths of any electromagnetic emissions we observe. Whether the emissions are in the shorter wavelengths of visible light or the long ones of radio, the Doppler effect will shift them one way (a red shift) for a body in recession or another (a blue shift) for a body that is approaching us. The greater the relative velocity of approach or recession, the greater the shift.

If we assume that the gas between the stars orbits the galactic center in the same differential-rotation pattern that Oort found for the stars, we can deduce the distances of the interstellar hydrogen atoms that emit radio waves. The way to do that is by observing the Doppler shift, which spreads the interstellar hydrogen's 1,420-megahertz radio emission over a modest band of frequencies. The strength of the radio emission at each frequency in this band will reveal the number of hydrogen atoms at the specific distance that produces that particular Doppler shift. Combined with measurements for the entire sky, this information enables us to map the distribution of hydrogen atoms in the Milky Way.

CHARLES O'REAR

Butler Burton has spent much of his career at Leiden University, where he helped revive the Dwingeloo telescope.

board that oversees the use of the telescope at Dwingeloo.

Burton arrived at Leiden at a time when the Dwingeloo antenna was being eclipsed by new devices, such as the world's largest steerable radio antenna, a 100-meter dish near Bonn, Germany. With only a quarter the diameter, and hence just 1/16 the collecting area of the German titan, the Dwingeloo antenna fell from the front lines of astronomical research during the 1970s. Dutch radio astronomers devoted more attention to their nearby array at Westerbork, where 14 25-meter dishes work in tandem to make high-resolution maps of small parts of the sky. By 1986 Burton learned that the Dwingeloo antenna was threatened with demolition. If he could find a worthwhile use for the dish, and a way to employ it without spending significant amounts of money, he could have plenty of time on the antenna—in fact, just about all of it.

Burton was sentimental about the Dwingeloo telescope. "Nostalgia is not a good motivation for scientific work," he notes, "but then not all motivations can stand the light of day." Like other astronomers, he also wanted a better survey of interstellar hydrogen atoms for comparison with new observations of interstellar matter in the infrared, as made by the IRAS satellite during the early 1980s, and in X-ray wavelengths, made by the new ROSAT satellite. Comparison of the three measurements would enable astronomers to determine a great deal about the temperature, composition, and motions of particular clumps of matter in interstellar space.

It could also help astronomers pinpoint areas where conditions were ripe for stars to form, because the density of gas in these regions rises well above average. Astronomers have a rather easy time spotting star-forming regions, which produce large amounts of infrared radiation—from the heat of the condensing stars—or even visible light from the newborn stars, as in the Orion Nebula. Because astronomers understand the later stages of star formation much better than the slower and more tentative earlier phases, they would dearly love to study an array of potential star formation sites in detail, hoping to determine just what triggers the mechanism that, a few million years later, will yield a cluster of stars like the Orion Nebula (see "Let There Be Light," Dec. 1992/Jan. 1993). These regions emit little infrared or visible light; instead, they produce mainly radio emissions from relatively cool atoms and molecules, such as molecules of hydrogen and carbon monoxide. By the time the gas clouds are on the verge of collapsing to form stars, they consist mainly of hydrogen atoms that have paired to form molecules, which do not emit radio waves at 1,420 megahertz. It is the phase before this that astronomers can study with radio maps like the ones the Dwingeloo telescope could provide.

Faced with the loss of the antenna, Burton reflected on two facts. First, the largest antennas observe small areas in such fine detail that they can never be used to map the entire sky: completing such a task would require not years but decades, depriving astronomers of the time to study interesting individual objects. Second, radio receiver technology had advanced enormously during the 1970s and 1980s.

Burton realized that even though the Dwingeloo antenna could not observe with any greater angular resolution—the fineness of detail visible at any single frequency—than it had before, its receivers could detect weaker emissions and "see" velocities with far greater precision than it had before. "What had changed was not the antenna but the detector technology," he says. "If the telescope could be fitted with state-of-the-art electronics, it would still be useful, at least if it could be dedicated to a project for a long time to compensate for its small size."

In fact, the telescope's receiver was a good one. The spectrometer, the instrument that measures the strength of emission at each particular frequency, was "the best in the world," a duplicate of one nearing completion as part of the equipment for the Maxwell radio telescope in Hawaii.

Burton perceived that in an era of limited funds, all that was lacking to make a greatly improved map of the Milky Way was someone willing to collect a few years' worth of data and devise a way to process it without spending much money. He found his candidate in Dap Hartmann. In 1979, Hartmann, who grew up in and around the Hague, had arrived at Leiden University. A budding physics student, he had been inspired to change fields by an astronomer who pointed out that "for the first year, astronomy is just physics, but with two extra courses. If you don't like the extras, drop them and you will find yourself doing physics after all."

Even more fateful for Hartmann's career was his interest in computer chess programs, a field in which the Dutch are leading players. In 1981 he and a collaborator decided to enter the first Dutch computer chess tournament, and plunged into the intricacies of programming computers for victory. "That basically taught me programming," Hartmann says. "You have to be re-

sourceful, you have to think of smart ways to do something. You have to think of good and fast algorithms and implement them in the most efficient way." Hartmann has been the president of the Dutch Computer Chess Society for the past six years—he finished third in the 1994 tournament—and has learned more about computer programming than most scientists ever do. "I would have been in big trouble without computer chess programming," he says, "because almost every day something comes up that requires at least ten lines of programming without doing something bad to the rest of the program."

In 1987 Hartmann was looking for a good thesis project when Burton suggested he use the Dwingeloo telescope to map the radio emission from neutral hydrogen atoms. At the time neither suspected that Hartmann would work on the project for nearly seven years. But Hartmann shared Burton's belief that the telescope ought to be kept alive, and he was willing to devote a fair fraction of his life to the effort. What appealed most to him was the feeling that this would be a do-it-yourself sort of project. "The telescope was given to us," he says, "and if it didn't work, it was up to us to get it running again."

In 1988 the Dutch National Science Foundation approved funding, and the survey project was ready to move forward. Although the telescope had a modern receiver and amplifiers, some of the latest electronic equipment was still in a prototype state and had not yet been debugged. No software existed to set the telescope's schedule and guide its observations. After Hartmann devoted nearly a year to getting the entire system into functional trim and writing the necessary software, he had an instrument that could measure the sky's radio emissions at intervals of half a degree, about the same angular spread as a full moon. The system could record the radio emissions at a thousand different radio frequencies simultaneously, enabling Hartmann to determine how many hydrogen atoms, moving at each of a thousand different velocities with respect to Earth, were emitting radio waves along any particular line of sight.

To map the sky visible from Dwingeloo, Hartmann had to observe in about 350,000 directions (it takes that many full-moon-size pieces to cover the entire sky visible from the site), record the thousand or so data bits received from each, and analyze the resulting collection of two gigabyte's worth of raw data. The routine work of the survey was rudely interrupted twice: when a vandal attacked the control room, and again when a leaky roof threatened to short-circuit the computer. Fortunately, the vandal didn't destroy any of the essential equipment, and the water, though coming perilously close to the electronics, was stanched in time. Then there were lesser dangers, such as obstacles placed by tourists on the railroad track that supports the telescope, and the crumbling of the old railway ties themselves. These too proved little hindrance.

As the key to success on a low budget, Hartmann completed the entire mapping project using ordinary personal computers—plus the knowledge he had gained from his years as a chess programmer. "I'd grown accustomed to a PC," he says, "and I didn't want to change. And I thought this was like teaching a computer chess: Just as I'd programmed my chess computer to make its own decisions, I wanted to create a computer program that would reduce the data on its own, to avoid all the subjectivity that humans would introduce. So I 'taught' the computer to make decisions."

Hartmann began the survey project using a (now) old-fashioned computer with a 40-megabyte hard disk. He had to use 500 floppy disks to store the survey data. "It was like moving a household with a bicycle, one load at a time," he recalls. Eventually, he graduated to a PC with a hard drive capable of holding the entire survey data. "One man, one processor—that's the way to go," he notes.

Now, with the survey completed, Hartmann is off to Harvard as a postdoctoral fellow. "Leaving the telescope was like saying goodbye to an old friend," he says. "You know he's got to go, but your heart bleeds. For six years I felt that the telescope was mine; now others are using it. That hurts a little."

The maps he leaves behind reveal the radio emission from hydrogen atoms in the Milky Way with a clarity never before available. This clarity is not, however, the product of improved angular resolution. That would require a much larger radio telescope. The receiver can detect some weaker emissions, but the greatest improvement resides in the velocity resolution—the fineness of spacing between one set of velocities and the next. While the new survey cannot refine the calculations of the amount of hydrogen in interstellar space, it can distinguish between hydrogen atoms with velocity differences of just half a kilometer per second, giving astronomers a better picture of how much gas lies at different distances from the solar system. "We've opened the window wider,"

For seven years, Dap Hartmann worked with the Dwingeloo telescope to map neutral hydrogen atoms.

SUSAN LAPIDES

says Butler Burton, "at least ten times wider than any previous survey." Think of it as a new national census that counts the same number of people but more precisely determines how that population is distributed county by county.

That may not be a great leap forward in our knowledge of the Milky Way, but it is yet another step, part of the ongoing journey to a better understanding of the cosmos. From his years at Swarthmore, where astronomers had spent decades carefully measuring the positions of stars in the sky, Burton learned the value of long-term survey efforts. "The work impressed me with the need for patience," he says. "I worked many nights knowing full well that the plates I took were part of an effort going back 50 years and likely to continue for many more years before the stars would reveal their motions." Burton likes to compare his work to the survey of the western United States that Lewis and Clark made nearly two centuries ago. "We deepen our knowledge so that others can build on it," he says.

The Dwingeloo survey shows the radio emissions from hydrogen atoms, with yellow indicating the strongest emission and dark red the weakest. The map below covers the entire sky (black areas show the parts of the sky that are never visible from Dwingeloo). The views above show the map projected onto the celestial sphere, as seen from four perspectives. These maps plot only the radio emissions arriving from regions that are approaching the solar system at velocities between 22.5 and 25 kilometers per second. The entire survey can be depicted only with dozens of these maps, each one showing the radio emissions from hydrogen atoms that have a particular velocity with respect to our solar system. From careful study of these data, astronomers can determine just how many interstellar hydrogen atoms lie at different distances from the solar system. In addition, by studying the structures into which the interstellar gas has clumped, and the motions of gas within those structures, they can search for regions where stars will soon form. This map reveals long filamentary structures spread over hundreds of light years—too large to be star-forming regions but highly interesting to astronomers nevertheless.

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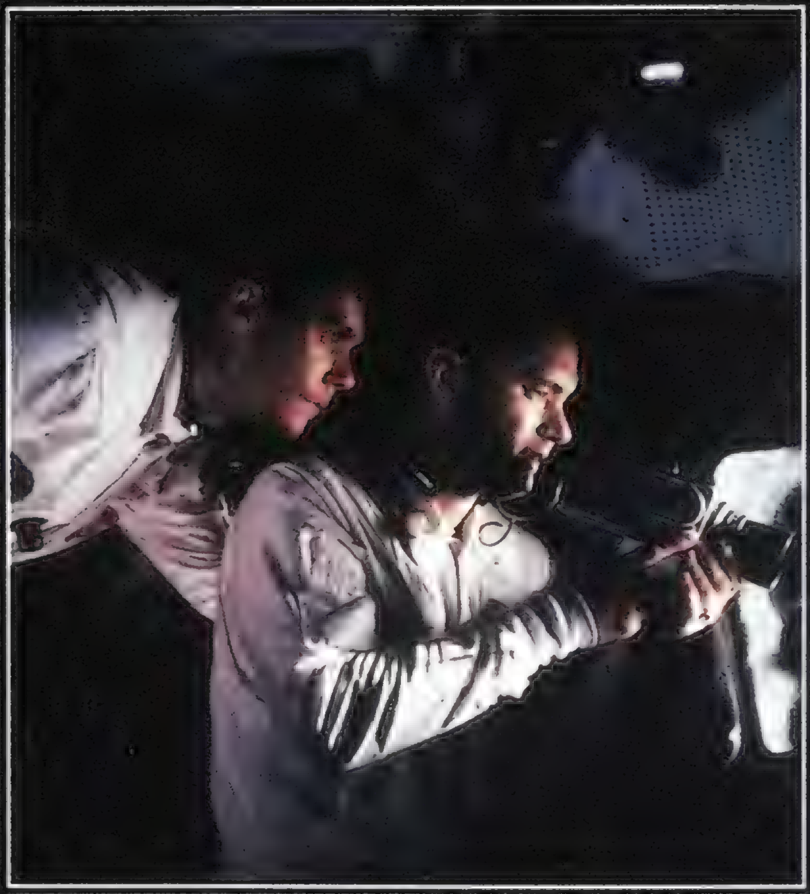


“Houston, We Have a Movie.”

Will *Apollo 13*, Hollywood’s latest space movie, repair the reputation of a mission that history recorded as a failure?

BLACK & WHITE PHOTOS: NASA; COLOR PHOTOS: UNIVERSAL CITY STUDIOS INC.

by Henry S.F. Cooper Jr.

Outside Stage 36, one of dozens of identical, shabby, utilitarian buildings on the lot of Universal Pictures near Hollywood, the air was balmy and the temperature was in the high 70s. But when I arrived last December on the 76th day of the shooting of *Apollo 13*, several fur-lined parkas, heavy tweed Inverness coats, and sheepskin jackets dangled on a coat rack outside the door.

Inside, the scene resembled the action at the bottom of a Manhattan manhole on a cold night, with a Consolidated Edison crew hard at work. The windowless room, the size of a basketball court, was pitch black except for a blaze of spotlights at the center, where a mockup of the Apollo 13 lunar module, *Aquarius*, hung on ropes suspended from the ceiling. The shadowy forms of about 40 actors, directors, producers, technicians, sound experts, photographers, and grips moved purposefully about, shapeless in bulky winter

Their cliffhanger voyage almost over, the Apollo 13 astronauts photographed their damaged service module shortly after jettisoning it. Between the command and service modules is the moon, tantalizingly visible but out of reach. In a movie about the mission, Kevin Bacon and Tom Hanks play astronauts Jack Swigert and Jim Lovell (inset).

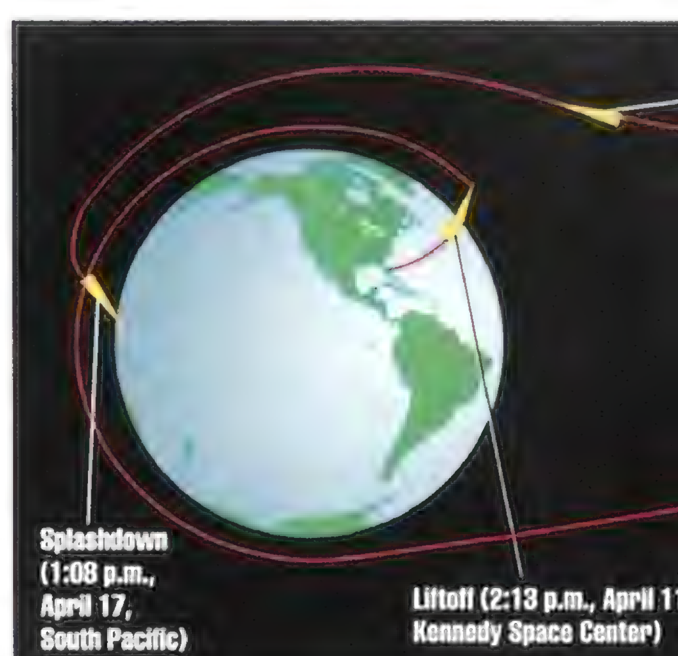
attire. Cables, wires, and hoses snaked across the floor, occasionally tripping a moviemaker. A huge humidifier noisily shot a giant jet of vapor into the air. Talking was next to impossible over the roar of the pumps and compressors of an enormous air conditioner.

In the icy chaos I recognized David Scott, the commander of the Apollo 15 mission. He was serving as a consultant on the movie, which is based on the book *Lost Moon* by Jim Lovell, the commander of the ill-fated mission, and Jeffrey Kluger, a writer with *Discover* magazine. Scott later made it to the moon with Apollo 15. Apollo 13 wasn't so lucky. The stigma that has dogged the mission ever since seems certain to disappear when the film reaches theaters this summer.

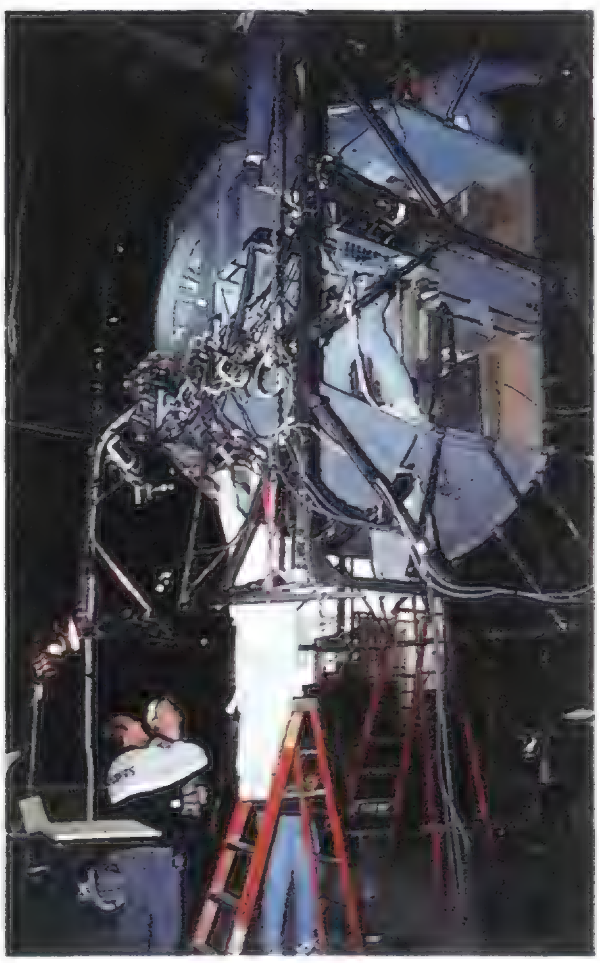
Motion pictures depicting spaceflight have been with us ever since Georges Méliès made *Le Voyage dans la Lune* in 1902. Since that flight of fancy, movies attempting re-

For three days astronaut Jim Lovell (above) and his crew endured a cramped and uncomfortable existence on their way back to Earth. To prepare for the role of mission commander, Hanks (left) visited and flew with Lovell.

alistic depictions of spaceflight have ranged from Fritz Lang's 1929 *Frau im Mond* (*The Girl in the Moon*) to 1983's *The Right Stuff*, with many others in between. Still, *Apollo 13* sets new standards for its extraordinary efforts to ensure accuracy, both on the ground and in orbit. Last October the actors traveled to Space Camp in Huntsville, Alabama, to prepare for their roles. They



also got a sense of weightlessness by spending three days flying giant parabolic arcs aboard NASA's KC-135 at Houston's Johnson Space Center. The movie's command module mockup, which also flew aboard the KC-135, is accurate down to its 500 switches, knobs, and dials (but built like a Rubik's cube so that parts of it can be removed for the camera to shoot from different angles). The filmmakers duplicated the Mission Operations Control Room in NASA's Johnson Space Center down to the graphics on the screens, the location of the electrical outlets, and the cigarette packs, Coke machine, and even the doughnuts—a brand called Shipley favored in the 1960s by flight controllers. The Lovell family house was replicated so faithfully that when the Apollo 13 mission commander saw it, he told me, he felt he'd gone back in time 25 years.



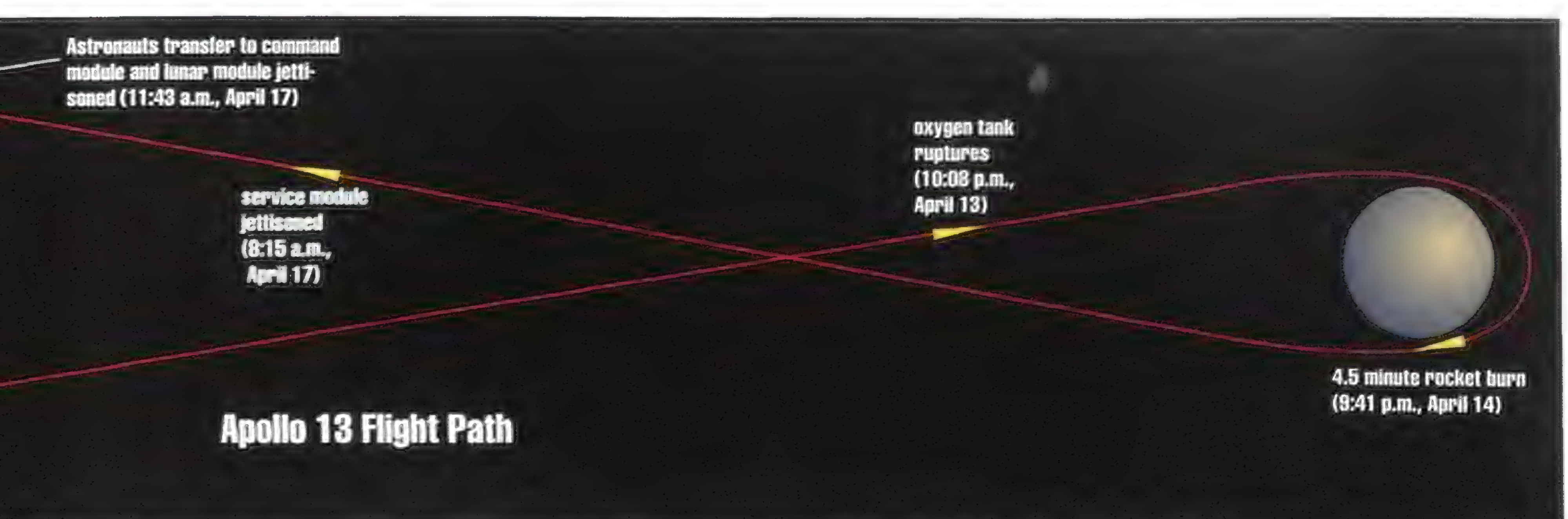
On April 13, 1970, two days and some eight hours after Jim Lovell, Jack Swigert, and Fred Haise had lifted off from Kennedy Space Center in Florida, an oxygen tank for the fuel cells that generated electricity aboard the spacecraft ruptured in the service module, resulting in a total loss of power in the command module. "Houston, we've had a problem," Lovell matter-of-factly reported to the ground. Too far along to return directly to their home planet, the astronauts had to coast around the moon. During the three days and 15 hours of the return trip, they used the lunar module as a lifeboat and also as a tugboat to make the critical rocket burns that would bring them home. Intended to land Lovell and Haise on the moon, the lunar module had only enough battery power and consumables for about two days, so the astronauts had to conserve electricity and water. The temperature inside the spacecraft plunged to 38 degrees, and the astronauts' breath condensed on the interior walls. The command module was the only craft that had a heat shield and thus the ability to withstand reentry, so in the last hours of the flight the astronauts had to power up the cold, dead spacecraft on its batteries (which had never been done before), then jettison the service module and the lifesaving lunar module. When they returned to Earth, they were exhausted but safe.

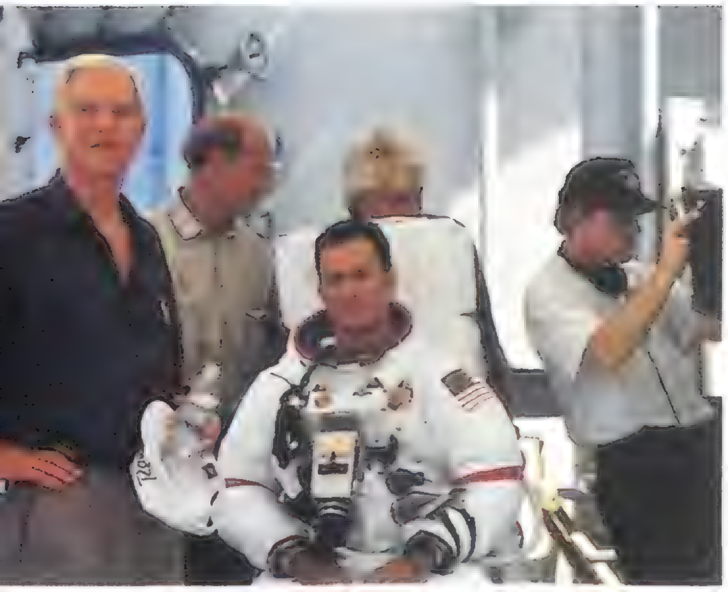
The Apollo 13 lunar module was intended to land on the moon; instead it functioned as a space lifeboat on a looping trajectory (below) around the moon and back to Earth. On the set, the exterior of the spacecraft mockup (left) bears little resemblance to the real thing, but the interior is accurate down to its console switches (opposite).

Apollo 13 was quickly forgotten. "NASA wanted to get away from Apollo 13, get it behind them. They thought it might hurt funding for the later Apollo missions," Lovell told me last October when he was in New York for the first leg of a tour to promote his book. The command module was even exiled to France. For a long time Lovell didn't know where it was. Then five years ago a Naval Academy classmate found *Odyssey* in a small museum at Le Bourget Airport outside Paris. Lovell visited the command module, which is still charred from the heat of reentry. "It looked kind of sad," he said. "The control panel was gone, the seats were out."

Lovell's book has helped resurrect the reputation of the Apollo 13 mission. The decision to make a movie out of the book was largely due to Mike Bostick, a senior vice president at Imagine Entertainment and now the film's associate producer. Bostick is the son of one of the key flight controllers for Apollo 13, Jerry Bostick.

"When Mike Bostick brought the script to our attention, he brought an extra degree of power because of his father," said director Ron Howard. Mike Bostick, now 32, had been seven years old at the time of Apollo 13; he grew up in Nassau Bay, Texas, across the street from the Johnson Space Center. His neighbors were astronauts and flight controllers and their families; they were in and out of one another's houses all





Apollo 15 astronaut Dave Scott (top, at left) served as a consultant to the moviemakers. Below, director Ron Howard is flanked by Bosticks Mike and Jerry. Mike suggested the story idea to Howard; father Jerry was a flight controller for the real mission.

the time. He was a classmate and friend of Fred Haise's son. Yet Bostick had never paid much attention to space or to his father's work. In fact, when his father took him to the Kennedy Space Center in the early 1970s, he wouldn't get out of the car—he didn't want to waste time getting to Disney World.

Consequently, the production had a special resonance for him. "The more research I did, the more I unearthed what had happened—and for the first time I got an understanding of what my dad had been doing all these years," Bostick explained. He was thrilled to have the opportunity to work with his father. "Now here I am at 32—who would have guessed our lives would have converged in this way?"

The Bostick connection grew more important as time went on. Jerry Bostick, the lead flight dynamics officer, along with Gerry Griffin, an Apollo 13 flight director, spent six weeks at Universal Pictures as consultants for the mission control scenes.

The two Jerrys, as they were called, taught a class that was meant to last two hours but ended up going for two days. The actors were given tapes of the Apollo 13 air-to-ground conversations and the flight controllers' conversations so they could pick up the cadence and the technobabble. Jerry Bostick was amazed at the depth of the actors' interest in Apollo: "I assumed the actors would say, 'I'm an actor. All I care about is my lines. Who is this NASA nerd?' " During the filming the two Jerrys also made sure that the data on the console screens were appropriate for the part of the mission depicted. When the translunar trajectory figure 8 was inadvertently reversed on the large screen at the front of the control room, the two NASA veterans pointed out the error.

"Early on, we made the decision that the more accurate we were, the more interesting the movie would be," director Ron Howard said later. A large part of the responsibility for accuracy fell to Dave Scott, who took the job as consultant because Jim Lovell was on his book tour. "Part of my job is listening to the dialogue, to see if the inflection is in the right place—things like that," he said. "I don't catch many mistakes anymore; they're pros. These guys are capable of a steep learning curve—once they do a couple of rehearsals, they really have it. When I listen to them, it's hard to believe they're not real pilots. They're deeply into it. They ask me all kinds of questions—what is this switch for, what does that gizmo do. And they want to know the reasons behind everything they do. They drive me back to the manuals. I have to do lots of homework. Three weeks from now we could put them in a real Apollo spacecraft and send them to the moon," he said, only half-joking.

Scott, wearing a red parka, is a large man who looks very much the way he did in old NASA photographs, except that he is somewhat larger and has more lines in his face—an unusually open and cheerful one. He said that he had gotten more attention from his children for his work in this movie than he had when he went to the moon in 1971.

Standing next to Scott was Bill Paxton, who had been in space before as a futuristic marine in the science fiction thriller *Aliens*. Like the other astronaut-actors, he had a three-day beard growth. After Paxton was summoned to makeup, Scott explained that at the point they were now shooting, Paxton's character, Fred Haise, was beginning to come down with a urinary tract infection and fever. "When makeup gets through with him," Scott said, "he'll look much worse."

They were about to begin shooting a rocket burn, the firing of the lunar module's descent engine that would hasten the spacecraft's return to Earth.

Actor Ed Harris (right) plays flight director Gene Kranz in the film. The film crew replicated mission control right down to Kranz's sartorial splendor.

The loud air conditioning and humidifying machinery was turned off. There were calls for silence. Tom Hanks, who is playing Jim Lovell and has something of Lovell's earnest face and quick smile, was wearing white Apollo coveralls. Made of Beta cloth like the real astronauts' suits, they reflected the spotlights brilliantly. Hanks took a sip of a hot drink from a cup, which he concealed behind the lunar module's control panel. The drink would make his breath more visible in the air, which was kept at 38 degrees—the same temperature as that in the lunar module. The humidifier made breath show up even better.

To create a diffuse look for the camera, a technician was making smoke from a machine and fanning it into the set; not only was the lunar module mock-up cold and damp from condensation, it was also foggy. Ron Howard, looking at the scene through a monitor that gave a camera's-eye view, thought there was too much smoke, and he held up the action until the fog was just right.

"You guys ready to try this?" said Hanks. "Then let's go...Ignition!" A burly technician shook the mock-up of *Aquarius*, as the spacecraft would be shaken in a real burn—the reason that it was suspended from ropes. The camera also was suspended on a rope and the cameraman was shaking it too, so that the audience would feel they were inside the spacecraft.

Scott thought the shaking was too much and mentioned it to Howard, still at the monitor. The director nodded and cut the action, telling the technician he wanted a less spirited burn.

The action during the burn had seemed intense—in fact it was more intense than it had been in real life. Earlier in the week, when the scene was first being set up, Scott had been away, and the actors had called Jim Lovell to get his advice about the intensity of the scene. Lovell had agreed that, although he, Swigert, and Haise had been the epitome of astronaut cool aboard the spacecraft, a little extra intensity was in order for the movie. Scott, when he returned, approved what they were doing. "The real problem of flying a manual burn with the LM [lunar module] docked to the much bigger command and service module is you have to do the reverse of your natural instincts," Scott said, referring to the fact that the lunar module functioned like a small tractor backing up a large trailer. "And you have three guys flying it instead of one. And one of them—Haise—is feeling poorly. So being a little emotional is justified."

For the rocket burn, Hanks had asked Scott exactly what he should be doing with his hands on the pitch and yaw controls. Scott had explained that for each motion the spacecraft was to make, Hanks had to turn on one thruster on each of four thruster sets, called quads. "I spent 15 minutes showing him," Scott said. "He wants to know not only how to do things right, but why."

I asked Scott if Hanks reminded him of Lovell. "Yeah," he said. "He's being more of a generic commander, but he also hits Jim well. You know he will get these guys through."

A young woman with a clipboard rushed up to get Scott's signature on some last-minute changes in the script. "The sentence should not be 'We need time for alignment platform' but 'for platform alignment,' " Scott corrected, penciling in the change.

Last-minute script changes were common. In this case, because the rocket burn that would return the astronauts to Earth was so dramatic, Howard had decided to spend more time on it than it had taken back in 1970. The screenwriters—planning on the shorter burn—had only written four lines of dialogue. "We can't have the guys just floating around saying nothing," Scott said. As usual, the extra lines had been written a few days earlier by the actors, Howard, and Scott. The changes could only be made by the people on the spot, Scott said, and they were always within the context of what the screenwriters had written. Each scene was rehearsed and finally scripted two days before it was shot; everyone was constantly shooting one scene while they were making script changes and rehearsing the next.

Sometimes the actors contributed new material. For example, they had asked Lovell if any of the Apollo 13 crew members had ever lost his temper. "Lovell said there was a moment when tempers flared—as is usual for three guys who are cold and tired and cramped in close quarters," said Hanks. "Lovell did not tell us what happened—he said

and William Broyles Jr.—started the script, Lovell and Kluger had written only one chapter of the book, so the screenwriters had little to go on other than Tom Wolfe's *The Right Stuff* and old *Life* magazines. As a result early drafts had portrayed the astronauts as hard-living, macho guys with Corvettes. This bothered both Lovell and Hanks. Lovell immediately began campaigning for kinder, gentler astronauts. "I don't even know what the Right Stuff is," Lovell told me.

The screenwriters added a subplot built around the replacement of Ken Mattingly, who had trained to be part of the Apollo 13 crew. After being exposed to German measles, Mattingly had been replaced by Jack Swigert two days before launch. The implication in the film is that Lovell and Haise—who had been particularly close to Mattingly—don't have full confidence in their new crew member. As Lovell described it, "They have Haise and me looking at each other and raising our eyebrows.... They play up that uncer-

The vast ocean is difficult for staging scenes, so the film crew used the back lot at Universal Studios for the splashdown sequence. The real recovery (below) took place 600 miles southeast of Samoa in the Pacific.

he never would." Still, the actors stuck a few harsh words into the script, confident that they were right in spirit if not in fact.

Because of the medium's abbreviated nature, many things had to be condensed in the film; there are only two major rocket burns in the movie as opposed to the four (plus some smaller ones) that occurred during the mission. The three shifts of flight controllers have been condensed to two. And the characters of the flight controllers are telescoped together—Jerry Bostick told me that the character that has his name is actually a composite of several flight dynamics officers.

When the screenwriters—Al Reinert

tainty all the way through, until at the very end—at the time of entry—Haise and I have full confidence in Swigert. But it wasn't that way at all—we had confidence in him all along." Lovell brought the matter up with the screenwriters, but he said he didn't push it.

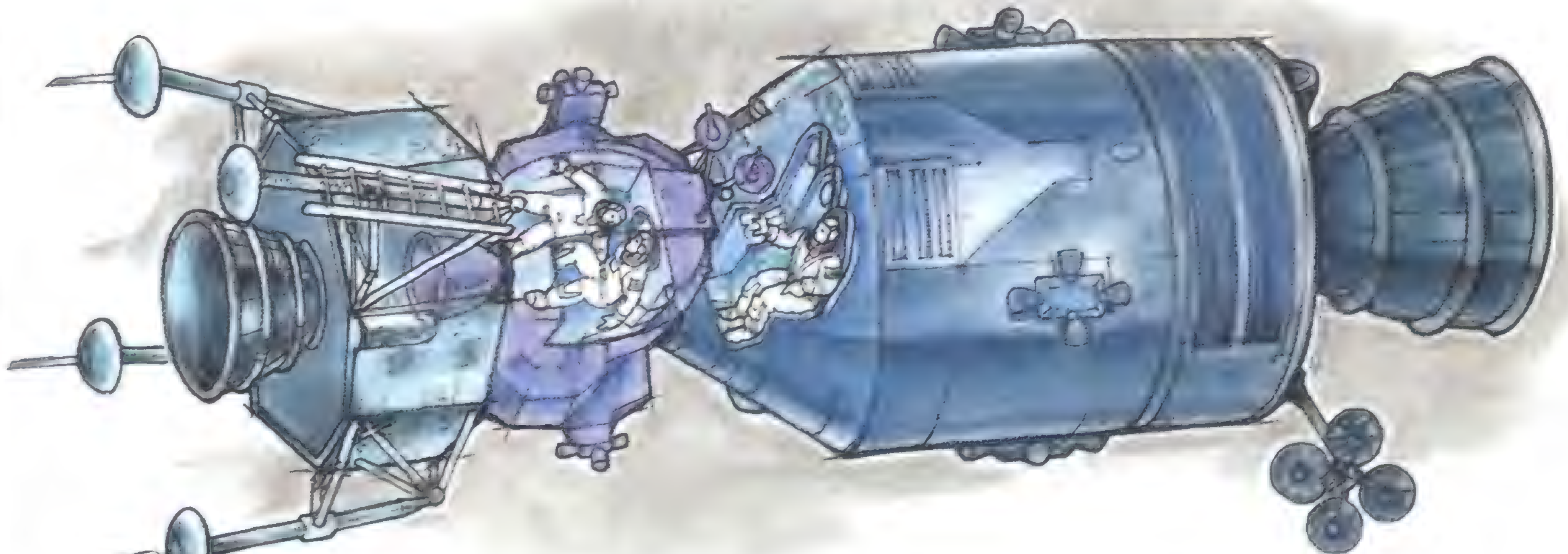
On the set, it was Kevin Bacon's turn to be filmed. Most of the actors were playing living people, which allowed for them to study a real person as a model. Bacon was portraying Jack Swigert, who had died of cancer in 1982. To compensate, Bacon studied Swigert by watching videotapes and talking to people who had known him.

While he wasn't busy on the set, I asked Hanks, an easygoing person who projected a mixture of intelligence and decency—his stock in trade as an actor—if the cold and damp helped his acting. "It makes us appropriately miserable," he replied matter-of-factly. He said that he, Paxton, and Bacon got on well together; they hadn't known each other beforehand, but preparing for the film had given them time to hang out together—a help to actors playing a tight, three-man crew. The best part of the training had been flying parabolic arcs in the KC-135. Footage was shot aboard the "Vomit Comet," and the flights also gave the actors an opportunity to experience weightlessness before having to simulate it on Stage 36. "It was like acting in a baseball movie and getting to play with Joe DiMaggio," said Hanks. "You see everything floating around you, and you're floating around yourself—it's a sensory experience you'd never get anywhere else. To make a movie about space without going into weightlessness would be like doing a movie of scuba diving and not going underwater."

I asked him if Dave Scott was a help in getting things right, and he nodded emphatically. "He gives us the procedures," Hanks said. "He's answered a million questions about what it's like up there. He tells us how to click all the little switches. He tells us what equipment is on at different times in the mission. If something is out of place, he tells us. If I'm looking for stars out a window for an alignment, he will stop me and tell me that from that particular window I will only see the CM [command module]—I have to switch windows. Then he will tell me what stars I'm looking at. He helps our acting a great deal. And if we want to make changes in the script, he will give us just the right amount of leash. He's an interesting guy."

I asked Hanks to what extent he was trying to mimic Lovell. "It's hard to do a full-blown interpretation of Jim," said Hanks, who spent four days with Lovell at his home in Texas. "He does have his own way of standing and talking—and there are several places in the script

JAN ADKINS



Apollo 13's difficulties stemmed from an electrical short that caused an oxygen tank to explode (on the far side of the service module in this depiction), cutting off electricity to the command module. The three-man crew transferred to the lunar module to save the command module's scarce reserves. The crew had to conserve power, water, and other consumables during the three days it took to return to Earth. They used the command module as the "upstairs bedroom," although it was usually too cold for sleep. Prior to reentry the crew returned to the command module and the protection of its heat shield. The service and lunar modules were both jettisoned and burned up when they reentered Earth's atmosphere.

A director and his crew: Ron Howard poses with actors Paxton, Bacon, and Hanks.

An exhausted but beaming Fred Haise, Jack Swigert, and Jim Lovell received a hero's welcome aboard the carrier USS Iwo Jima. *In the movie, the* Iwo Jima *is played by another carrier, the USS* New Orleans *(above).*

when I can use those characteristics. But most of the action is in weightlessness, where he isn't standing, and most of the dialogue is quite stiff-lipped, so there isn't much room for Jim's own mannerisms. But I am able to use his cadences."

Hanks excused himself because the scene was starting and he was needed as a voice off stage. Without moving away, he said, on cue, "Bring it back! Bring it back!...Easy there, Fred-o!...Shut down!" When the scene was over, I asked him about his visit with Lovell. "I learned a lot of particulars, about what was going on at different parts of the mission," he said. "He had oceans of scrapbooks about the mission. And he had the real eight-ball and COAS [the navigation display and the optical alignment telescope] from the spacecraft."

Lovell, in turn, had enjoyed Hanks' visit. He had picked up the actor in his own airplane and flown him home. Even though the trip was only 50 miles, Lovell flew Hanks around for an hour or so to give him the feel of flying. At dinner, he told Hanks not to drink anything—they were going out again, to fly at night. He wanted to give him the feel of being an aircraft carrier pilot—how Lovell started his career. Night flight, of course, is similar to spaceflight, and later Lovell put a mask over the windshield, with a triangle cut out to simulate the lunar module window. He even showed the actor some of the guide stars he'd used on Apollo 13.

Hanks came back from his meeting with Lovell much relieved. "Beforehand, I'd been a little scared," Hanks said. "Who'd believe me as an astronaut? But Jim was the most easygoing of all the astronauts. Lovell is not glamorous. I've seen lots of old tapes of him on symposiums and panels with other astronauts, back in the 1970s. The most interesting guy there was Lovell. He always seemed to be sort of in the background—he knew that NASA wanted to forget Apollo 13. These must have been years in the desert for him—watching Apollo 14 through Apollo 17. During those missions, you see him hidden away in the geology back room. The other astronauts on those old panel discussions had all achieved their missions, but Lovell has a very different story to tell. When I found out what Lovell was like, it opened doors for me."

The rocket burn sequence would require more than a day of additional filming as the scene was shot over and over from different angles for the benefit of the editors who would assemble the movie later. In time, I felt as though I was inside another movie, not *Apollo 13* but *Groundhog Day*, in which actor Bill Murray portrays a man who lives through the same day over and over for a year.

Making a major motion picture is an intense and complex undertaking. "When I started out, I had no idea how involved I'd get—and neither did Ron," Scott said. The concentration involved in the production reminded him, in a sense, of flying a mission to the moon.

Perhaps the production has been inspired by the theme of the movie, which comes down to the triumph of the human spirit over adversity by means of skill and teamwork. Lovell's co-author, Jeffrey Kluger, had mentioned to me that Hanks seemed to have a particular affinity for people who triumph over adversity—the lawyer with AIDS in *Philadelphia*, the retarded Forrest Gump. When I asked the actor about this, he said, "I hadn't thought of that. Maybe he's discovered something about me. It seems I'm drawn to stories where there is a big flaw—either internal or as in this case external—that has to be overcome somehow."

Many people involved with the production were drawn to the classical elements in the story. "It's a great story," said Hanks, "with Mattingly bumped from the crew...and with Lovell going to the moon for the second time [after

Apollo 8] and not getting to land and fulfill his destiny. It's an incredible saga. It's from the Greeks." Screenwriter Al Reinert told me, "It's a classic adventure story. Going to the moon was an extraordinarily harebrained thing to do—like spending ten years besieging Troy for some woman. It's the kind of thing that Homer would have written if he had been around." The name the astronauts selected for the command module—*Odyssey*—and the emblem they picked for the mission—three horses, like those drawing Hector's chariot, galloping around the moon—reinforce the classical element.

I asked Howard if he thought the story was mythic. "I suppose it is," he said. "It really is an odyssey. But I make a conscious decision to avoid myths. I make popular entertainment. It's exciting to tell a true story—to say, 'Look at this extraordinary group of people and their accomplishments.' I try to make them real people. They're talented, dedicated, intelligent people—not exactly like the man on the street, but maybe you'd meet them at a school function and not think them unusual."

Still, the story had the makings of a great American epic. On their race around the moon, Lovell, Swigert, and Haise didn't have time to think that they might someday be watching a Hollywood depiction of their legendary flight. "I'm very happy, very flattered, that our flight is being made into a movie," Lovell told me recently. Though NASA had attempted to bury the story, the filmmakers, excavating the space agency's archeological midden, have discovered gold as pure as Priam's treasure.

The MiGs of the Luftwaffe

The pilots in Fighter Wing 73 used to fly on opposite sides of the Iron Curtain. Now they fly in the same squadron.

by Steve Vogel

Photographs by Mark Simon

When they flew for West Germany, Lieutenant Colonel Wolfgang Michalski (left) and Colonel Klaus-Peter Stieglitz found the MiG-29 a threatening sight. Now they regularly fly the former top-of-the-line Soviet fighter in a squadron that tests the limits of German reunification.

Along the Baltic plain in northern Germany, a sleek, gray needlenose jet roars down a long runway ringed by forest and screeches into the cold blue sky. Once a top-of-the-line interceptor for the Soviet Union and its satellites, this MiG-29 now belongs to Fighter Wing 73, a curious amalgamation of pilots who speak the same language, wear the same gray flightsuits, and patrol the same skies but, until a few years ago, were sworn enemies. While half of the squadron's 28 pilots once patrolled West German skies in Tornados and Phantoms, the rest flew on the other side of the Iron Curtain as members of the East German air force.

With the cold war a half-decade dead, it is perhaps no great shock to find MiGs under the control of North American Treaty Organization members. Yet after the German reunification in 1990, many in the Luftwaffe wanted nothing to do with the MiGs, their pilots, or any other remnant of East Germany's air force. Part of that attitude stemmed from a disdain for the enemy. Part of it was concern about the interoperability of two vastly different military systems. And part of it was economic: With the cold war over, Germany was drastically cutting, not increasing, its forces.

Indeed, the East German military has been disbanded and much of its equipment scrapped or sold to countries like Turkey or Indonesia. Other than a few transports and helicopters, the Luftwaffe retained only one type of East German aircraft: the MiG-29. Though the Fulcrum—its NATO code name—was one of the most feared weapons in the Warsaw Pact arsenal during the waning years of the cold war, many in the Luftwaffe scoffed at the notion that the aging Soviet jet could compare to newer and electronically superior western fighters.

But the Luftwaffe remains heavily dependent on 25-year-old Vietnam-era F-4 Phantoms, and the more enlightened among the Bundeswehr, the West German military, realized it might not be such a bad idea to add the MiGs to its arsenal, especially considering that efforts to develop and build a European fighter have run into endless political and financial problems. The Luftwaffe's MiGs are projected to stay in service until 2005. Some in the Bundeswehr, however, worry that with the recent acquisition of the MiGs, Germany may not feel the need to participate in the development of the new European fighter, which the Luftwaffe continues to insist it requires.

Adding the MiGs was also a bit of a sop to the East Germans, a gesture to show that despite all evidence to the contrary, the Federal Republic of Germany had not simply swallowed the German Democratic Republic and spit out the remains. The result has been something of a social experiment—a bright, shining, and rare example of an enterprise in which *Wessis* (West Germans) and *Ossis* (East Germans) do not constantly carp at each other and mutter that maybe the Berlin Wall was not such a bad idea after all.

Fighter Wing 73 is based at Laage, an air base built by East Germany in 1984 as home to two squadrons of Su-22 fighter-bombers. Ninety miles north of Berlin, the enormous base covers 3,000 acres amid farmland in the

Some of the MiGs still bear Cyrillic writing, a reminder of their Soviet origin. Nonetheless, as one of the fastest and most agile jets in the Luftwaffe, the Soviet jets have quickly become an integral part of Fighter Wing 73.

gently rolling, often rainy and foggy plains of Mecklenburg-Western Pomerania. It's located in what is by far the most rural German state, one of the few places in the nation where a drive in the countryside does not find every square inch of territory put to maddeningly efficient use. Woods, mostly pine, cover so much of the base that it has its own forester. Every six months or so, the base organizes a hunt, and local sportsmen blast away at wild boars in an effort to keep the runways clear of the beasts.

Laage is a new home for Fighter Wing 73, which was originally stationed at Preschen but moved last winter to avoid local flying restrictions and the Polish border. The closest city of any size is Rostock, an old Hanseatic League Baltic port about 15 miles away. The city made international headlines in August 1992, when bands of skinheads launched nightly attacks on a refugee hostel as local citizens cheered and police stood by. The MiGs have brought promise of some 300 jobs to this region still reeling from the closing of shipyards that were unable to compete after reunification. Unemployment in the area is a grim 18 percent.

Leftover symbols of its East German heritage are still very much in evidence at Laage. A Trabi, one of the oddly dependable little plastic cars once prevalent in East Germany, still provides occasional transportation around the base. Construction and renovation projects evince Luftwaffe attempts to raise Laage to western standards. On a bright, blustery day last December, even the pilots were hard at work scraping paint in the squadron operations room. There's little they can do, however, about the astoundingly ugly concrete buildings they've inherited.

It's generally not difficult for a visitor at Laage to guess whether a pilot is an *Ossi* or a *Wessi*. The westerners have broader smiles (and better teeth), louder laughs, and a bit more swagger. Considering what the eastern pilots have had to endure following reunification, the absence of swagger is no surprise. Former East German MiG pilots who wanted to join the Luftwaffe were given a take-it-or-leave-it offer that included a reduction in rank—in some cases, a drop of two levels (a standard policy toward East Germans joining the West German military). They were also required to undergo intensive study of English, the language of NATO. In ad-

dition, they would be educated in the ways of western democracies.

Of 47 East German MiG-29 pilots, 42 agreed to these one-sided terms for the same reason pilots everywhere would: They wanted to keep flying. "It wasn't a difficult decision. I've always been a fighter pilot," says Lieutenant Colonel Guenter Fichte. "It wasn't important what rank, but what job."

Lieutenant Andreas Zube, 31, a short and serious-minded Berliner, confesses to having had initial misgivings about joining the Luftwaffe. "In the beginning there was a lot of hesitation from our side as well as from those guys," he says, referring to the westerners. Zube had joined the East German air force in 1981 because he wanted to fly. "In East Germany it was the only way to become a pilot," he says. As an East German pilot, Zube viewed the men he flies with now as the enemy. Asked whether he viewed the NATO alliance as a serious threat, he replies: "Yes, of course. That was what we were taught and what we believed. It was also a matter of motivation. Otherwise we wouldn't have taken our states of readiness seriously." East German pilots had to be ready within minutes to go airborne 365 days a year. In contrast, the West German military was virtually closed by 2 p.m. on Friday afternoons, even during the most frigid periods of the cold war.

Lieutenant Colonel Manfred Skeries, 52, an intense but polite man with a hard, lined face, joined the East German air force in 1959 as a glider pilot. By the time of reunification he was a full colonel and chief of fighter-bombers. Like most officers in the East German air force, he had been a member of the Communist party. "Of all the problems of coming together, in my opinion, the biggest were ideological," he says. "First in coming to terms with the recognition that our own system and ideology had collapsed, and with that the economic and political systems.

"It was a system I had explained and defended to the troops," he continues, "as an officer of the [National People's Army] responsible for the political development of my subordinates. And that can only work when your heart and soul stand behind it. Now to understand that that was not right was the biggest problem. And it took me two or three years to understand.

"A secondary problem is the new social system, free democracy with travel, everything that comes with democracy. With distance I can see that we've gone from a dictatorship to a democracy, and it's naturally very difficult."

One odious legacy from the old system, the East German Ministry of State Security, or Stasi, returned to haunt several of the pilots. In January 1992, Germany opened literally millions of Stasi files to the public. Among the unpleasant revelations: Seven of the pilots in Fighter Wing 73 had informed for the Stasi, which was widely known for its destructive intelligence activities. A letter was sent to each pilot informing him of the allegations, and within days all seven were gone.

The Stasi outings had a demoralizing effect on the eastern pilots. "We had

Though not as fleet as the MiGs, a Trabi automobile that was also retained from the East German air force makes Lieutenant Colonel Guenter Fichte feel more at home. The former East German is pleased to be flying in the Luftwaffe. "It wasn't a difficult decision," he says. "I've always been a fighter pilot."

long discussions about it," says Captain Ronald Triegel. "Best friends for years didn't know that the other had been informing the Stasi. There was every reaction imaginable, ranging from disappointment up to anger."

Some of the western pilots expressed understanding. "If I had been a [National People's Army] pilot and the Stasi had said 'You have to work for us,' probably I would have done the same," says Captain Georg Pepperl.

The easterners also had to contend with western "know-it-alls," commonly referred to as *besser Wessis*. "We used to have problems at the beginning," says Colonel Klaus-Peter Stieglitz, the

swashbuckling wing commander and a westerner. "More than a few western officers came to East Germany like conquerors, tried to manage everything, always had the best perspective, and could tell everyone how to run their business—and that was not the correct way. In very extreme cases, we pulled them out and brought them back to West Germany."

"There are *Wessis* who have their noses in the air," says Sergeant Mario Baenz, an easterner. "There are others whom you can have a good relationship with."

But the superior attitude of the *besser Wessis* hasn't been entirely eradicated, at least in the cockpit. Former East German pilots were required to teach the intricacies of flying the MiG-29 to several top western pilots, who then turned around and retaught the easterners—many of whom had been flying the airplanes since they were acquired in 1988 and had even served as instructors. "It was a crazy situation," says Triegel. "To be trained by western guys was a little strange. But I couldn't change the situation. If I didn't show the proper attitude, I could be kicked out."

"They couldn't fly as well, and they could not handle the aircraft the way we thought was necessary," Stieglitz says of the easterners, with a tone suggesting that he still wrestles with the ghost of *besser Wessi*. "They did not fly the MiG-29 the way it could be flown, because they used a concept that did not use all its capabilities. We are flying the MiG-29 in a much broader fashion than they used five or six years ago."

To head the retraining program, the Luftwaffe chose one of its best pilots: Lieutenant Colonel Wolfgang Michalski. He developed a program of over a dozen increasingly difficult flights to help him evaluate whether the eastern pilots were capable of adapting to a western system. "Nobody really understood why we—as the new guys—would train them on the MiG-29," says the breezily friendly Michalski, who is squadron commander. "They said: 'We know it much better because we've flown it for years'—of course not knowing that our way of flying was totally different. I heard that opinion several times. But in the air I showed them"—he pauses to chuckle—"the hard way. Although I had far fewer hours on the MiG, I was just better."

The easterners had been trained under a more rigid system in which the pilots were constrained from taking individual initiative, relying instead on standardized maneuvers and on directions from the ground. "Their actual maneuvering was more canned than we are used to," says Michalski. "We have different set-ups for aerial combat, for air-to-air maneuvering, close-in maneuvering. Within those you can maneuver as you like, whatever's tactically sound. Whereas they had more or less prescribed maneuvers which they flew. The attacker's task was basically to maintain that position or eventually come in for the shot."

For eastern pilots who were used to having their every move choreographed by ground controllers, it was not easy to adapt. "Nobody's helping him from the ground, telling him there's a target," says Michalski. "Nobody's telling where to turn to, where to go, what to switch for and stuff like that. He would

The 28 pilots in Fighter Wing 73 have had to cope with a series of adjustments: new aircraft, new squadron members, and a new air base at Laage, in what used to be East Germany.

be lost almost immediately in space."

Despite his experience flying MiG-15s, -17s, and -21s before being trained on the MiG-29 in Kazakhstan in 1987, Manfred Skeries is quick to acknowledge he had a lot to learn. "The philosophy with flying was so different," says Skeries, who now serves as deputy wing commander. "Fighters—from ground to employment to landing—were permanently under [ground] control. It was always centrally controlled."

"I'll give you a really good example," says Captain Bernd Pfaehler, a westerner, sitting in the officer's mess with a group of pilots. "With our expensive jets, if we realize something is not going to work—not at all—we get the hell out of there and bring our jets home and try to set something else up. Those guys"—he points to an easterner—"would have been vectored in there, maybe without even knowing what was coming at them, and [would have] died."

Andreas Zube nods grimly. "The old tactics were based on conventional superiority," he says. "In those days there was no choice. It was mass force. If I'd come back, the next day I would end up in military court."

Now considered one of the best pilots in the squadron, Zube ruefully recalls his baptism by fire into western techniques. "The real surprise was the first time I went out in 1991, when I was only trained in the old tactics, the old maneuvering, and I lost against an F-4," says Zube, unable to disguise his disgust.

"He was very surprised," Michalski says, chuckling.

Seven of the former East German pilots quickly washed out. "They weren't able to adapt to this style of maneuvering and thinking," says Michalski. It was a brutal process—of the 42 East German MiG-29 pilots from the original group that trained in July 1991, only 13 remain. Yet those that survived the western training are now among its biggest advocates. Some three years after losing to an F-4, Andreas Zube has defeated F/A-18s and F-16s in mock combat.

Michalski admits that these days it can be tough to best the easterners. "I have more hours on the MiG than all the other pilots, but they've learned a lot and it's not so easy for me anymore," he says.

But the best pilots in the squadron are still from the west. "No doubt about it," says Michalski. "It's one thing to perform normal aircraft maneuvering, air-to-air maneuvering. The other thing is to lead and be responsible for two to four aircraft, and lead them back home and make all the decisions to bring them back safely. This is another story which they're not used to. The western pilot, of course, is used to that and sees no problem with it."

When a pair of pilots is needed, commanders tend to send an *Ossi* and a *Wessi* so that any extra experience the westerner possesses will rub off. But perhaps the main reason the easterners have improved is increased flying time. Warsaw Pact pilots typically had only a third of the annual flying time their NATO counterparts had. "Someone who flies only 60 to 70 hours per year has a different capability from a NATO pilot who flies between 200 and 240 hours per year," says Stieglitz.

By 1993, because so many former East German pilots had either washed out or left because of Stasi connections, western pilots were brought in to round out the squadron. Their training included a two-month program on the MiG, a somewhat surreal experience for them. "When we were training in the [1980s]," says Bernd Pfaehler, then a Phantom pilot, "the MiG-29 had just come out on [intelligence] reports, and that was our major hostile threat. And now I'm flying it—that was kind of strange in the beginning.

"I didn't encounter very many problems," adds Pfaehler, "except the cockpit was in Russian. I had to learn a little bit of Russian at least to read the cockpit switches."

The western pilots raved about the MiG-29's power and maneuverability, but they were less impressed with the pulse-Doppler look down/shoot down radar, which is not able to track an enemy aircraft while checking for other threats. In addition, the MiG's radar- and infrared-guided missiles were outranged by those of most top-of-the-line western aircraft.

"Why do you build such a great, highly maneuverable airplane and then have a very bad weapons system, radar, and so forth in the aircraft?" Pfaehler asks. "*That's* the problem we have, since we're trying to employ the MiG-29 in a western-type scenario, which it's not built

for: autonomous operations with fuel required, with situational assessments based on your own radar and radar warning equipment. You don't have that in the MiG-29. You can't do that. It's purely built for ground-controlled, intercept-type point defense."

Moments after landing his MiG, Lieutenant Frank Simon, another westerner, stands on the frigid runway at Laage issuing his own criticisms. "One disadvantage is its smaller fuel range," he

says. "In a combat situation you'd have to disengage after a short time. It comes from a different philosophy. The MiG can fly two hours on a training flight [with an external centerline tank]. But in a fight where you're using your afterburners, you could only last 40 to 50 minutes."

Western pilots are also less than thrilled with the MiG's cockpit set-up, which they say is not ergonomically well designed, and they complain that the throttle lacks thumb controls, which lessens a pilot's option for turning his head from the control panel.

Despite the deficiencies the Luftwaffe has made few changes to the MiGs, and those are largely superficial. Instead of the green camouflage the MiGs sported in the East German air force, they are now all painted gray to match other Luftwaffe aircraft. The labels in the cockpits are being changed from Cyrillic to English. Stieglitz says he hopes to improve the navigational capabilities of the MiGs by adding Global Positioning System equipment.

The MiGs have provided an education for fliers from both sides of the Iron Curtain. Former adversaries Captain Georg Pepperl (left), a Wessi, *and Lieutenant Andreas Zube, an* Ossi, *study a flying chart together.*

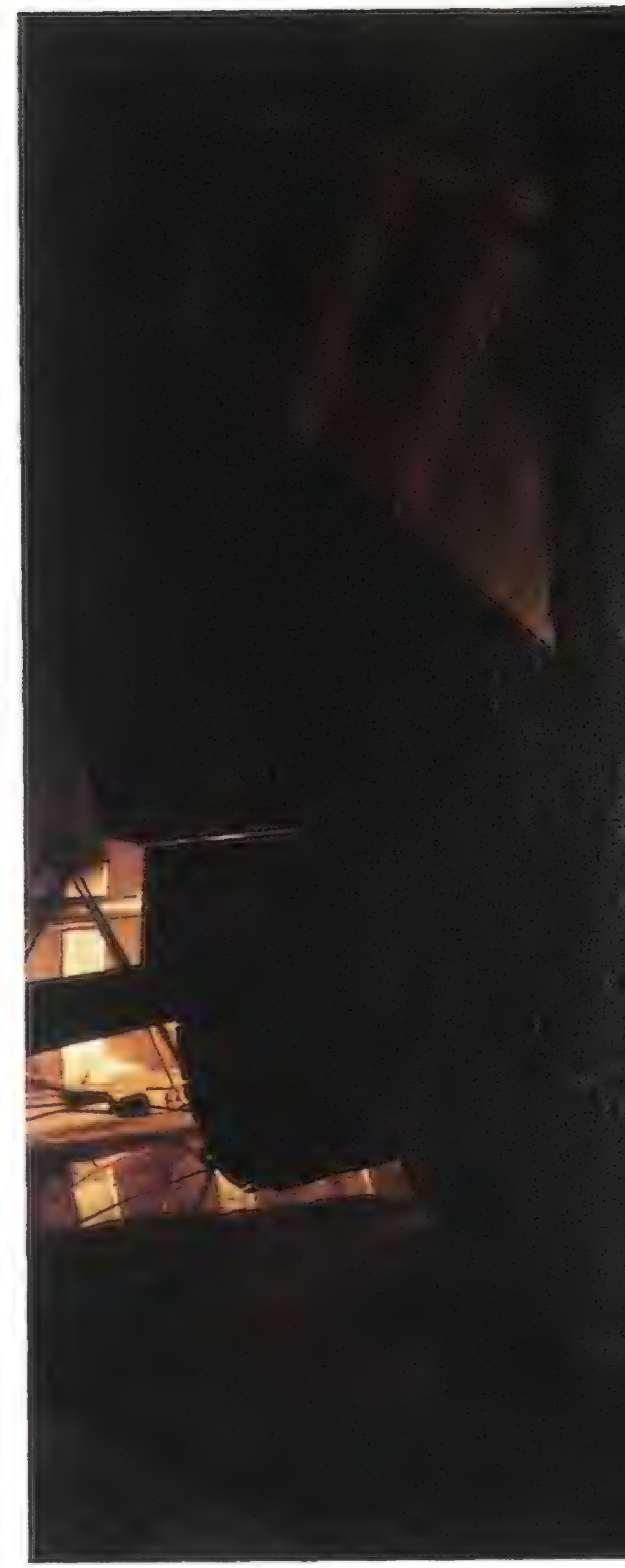
Another drawback is the difficulty of obtaining replacement parts. With the current economic morass in the former Soviet Union, requests for parts often disappear into a black hole. The problem is compounded by the fact that different components are made in different republics. "There are no problems with engines or engine parts, since they are built solely in Moscow," says Stieglitz. "But with parts from other countries in the former Soviet Union, there are problems getting them in a timely manner. It always takes a long time."

"It's two great bureaucracies colliding against each other—the Germans and the Russians," says Sergeant Andreas Flehr.

After three years of flying MiG-29s the western alliance has received quite an education in Soviet-built aircraft. Indeed, much of the value of the MiG-29 to the Luftwaffe (and NATO) is not in the additional capabilities it brings to the force but in the knowledge that alliance members, including the United States, have gained about the abilities of countries that use Soviet aircraft and doctrine. This includes potential foes such as Iraq, North Korea, Serbia, and, though no one will mention it, Russia.

The Fulcrum

The MiG-29 first entered service in 1985. Propelled by two Tumanski RD-33 turbofan engines, each providing 18,300 pounds of thrust, the low- and swept-wing fighter is capable of reaching Mach 2.3. East Germany received 20 single-seat and four two-seat MiG-29s, which currently belong to the Luftwaffe.



"It's a better force with the MiG-29 because now we have the chance to know Soviet-built aircraft...," says Stieglitz. "We understand their employment concept, we understand better their employment of air power and the value of air power within the Russian defense doctrine."

During NATO exercises, the Luftwaffe's MiGs have taken on the cream of the alliance crop in dogfights over the Mediterranean. The Germans find themselves swamped with offers from the Dutch, Belgians, Americans, and others eager to match their F-15s, F-16s, F/A-18s, Tornados, and so forth against the MiGs.

"They are all interested and keen to fly against the MiG-29," says Stieglitz. The pilots lounging in the squadron room at Laage say that the MiG-29 has not only been holding its own against aircraft such as the F-16 and F/A-18, it sometimes wins. "Not only sometimes," says Stieglitz, the slightest trace of a smile creeping across his face. "We have now reached a training standard with the MiG-29 where we can take on all types of aircraft in dogfight and combat situations, and the outcome depends, at least sometimes, on the pilot and the decisions he makes during the fight."

The consensus among the squadron is that the F-16—the MiG-29's closest American counterpart—is a better aircraft, despite the claims of many pilots that the MiG has greater maneuverability. "From long distances, the F-16 has the advantage, but in a close dogfight, whoever made the first mistake, it would be their last," says Simon.

"There are certain aspects where the MiG-29 is superior, but they are all small aspects," says Stieglitz. "In general terms, the western aircraft are superior, adding up all the avionics and radar and weapons and missiles and what have you. The F-16 has a greater range and better avionic capability. But we have our advantages, and if you stick to those advantages you have a good chance to survive against an F-16."

Next year the Luftwaffe plans to move a squadron of F-4s to Laage. "Each aircraft has its deficiencies and attributes," says Stieglitz about the F-4 and the MiG-29. "We'll bring them together to

Though procuring spare parts has proven difficult, the Luftwaffe plans to use the MiGs for another decade.

get a synergetic effect: the MiG-29, with its high maneuverability, and the Phantom, which has long range capability with respect to the MiG-29."

"The MiG can profit from the radar of the Phantom," continues Fichte. "The F-4 can profit from the agility of the MiG-29 in a fight. Of course, the best would be to have the radar of the F-4 on the MiG."

As the MiGs have been integrated into the Luftwaffe, so have their original pilots. They are learning that the altering of mindsets comes gradually. "Even after four or five years, it's not grown together like I expected," says Triegel. "Everybody's working together, but sometimes you can feel distrust."

"I think within the last four years my mind has changed, as well as the minds of the western guys," says Andreas Zube. "I think we're able to do good work. Information in the media, learning about what the Stasi had done, changed my mind about the former system."

Asked if he trusts his eastern pilots as much as his western ones, Stieglitz does not hesitate. "Yes," he says. "No difference."

And if the easterners ever had difficulty accepting western orders, the issue no longer exists. "There might have been problems or reluctance at the beginning," says Stieglitz. "But right now, since we've mixed the whole thing together, I don't think there's a problem."

But although friendships have developed and an atmosphere of collegiality prevails in the squadron room, pilots acknowledge that a certain separateness seems to guide off-duty hours. "Private contacts are rare," concedes Georg Pepperl. The former cold warriors will gather together occasionally at the pub for beers, but such occasions are more the exception than the rule. Still, *Wessis* and *Ossis* alike say their relations are comfortable and friendly. "From the beginning," says Bernd Pfaehler, "we had one common language, which was flying."

To Make a

by Frank Kuznik

Can something ever come from nothing? Alex Ignatiev fervently hopes so. Ignatiev, a University of Houston physics and chemistry professor, is scribbling equations for that very process on a board in his cluttered campus office.

Behind Ignatiev's desk hangs a sumptuous rendering of the shuttle in flight, deploying what might easily be mistaken for a backyard dish antenna. With its odd saucer shape, this spacecraft—the Wake Shield Facility—is designed to move through space pushing aside the few atoms it encounters, leaving in its wake an area almost perfectly devoid of matter—an ultravacuum. In this region, Ignatiev hopes to launch a new era of extraterrestrial manufacturing.

The electronics industry has long valued the vacuum—or, more precisely, the near-vacuum. While no one has ever created a true vacuum—an environment entirely free of matter—chambers used in electronics manufacturing can now produce an environment more than 10 trillion times sparser than the atmosphere at sea level. Such near-vacuum states minimize contamination by extraneous atoms, so these chambers are commonly used to produce materials that must have as pure an atomic composition as possible, such as semiconductors, the basis of the integrated circuits that run computers and other electronic devices.

The way Ignatiev and his co-workers see it, the wake shield will produce an environment far sparser than that achieved in any Earthbound vacuum chamber. And because a sparser environment results in a purer product, semiconductors manufactured in the wake shield's ultravacuum will be superior to those produced on Earth.

Or so the theory goes. On its maiden voyage in February of last year, the wake shield barely managed to equal terrestrial production standards. But three more flights are scheduled, the first of which is slated for July, and Ignatiev is hoping that each will result in a better performance. His ultimate goal is to have a second-generation wake shield in permanent orbit, continuously producing an industrial-scale crop of semiconductor materials that shuttle astronauts would periodically harvest. "The quality of the materials will surpass what can be done on the ground," Ignatiev says, "so we should be quite competitive."

The concept of a wake vacuum isn't new. In the 1970s NASA scientists published papers describing how a craft sailing through space will leave an ultravacuum in its wake much the way a powerboat leaves a temporary channel in the water behind it. But in the absence of practical applications, the idea languished undeveloped. Ignatiev resurrected it in the mid-1980s, essentially as an extension of the work done in his Houston labs, where powerful vacuum chambers are used for epitaxy—the making of thin films composed of precise crystalline arrays of atoms.

DAVID NANCE

The theoretical calculations were impressive. Atmospheric density is measured in "torr"; the pressure at sea level is 760 torr, that at the shuttle's low Earth orbit is 10^{-7} torr, and terrestrial vacuum chambers top out at 10^{-11} torr. Ignatiev calculated that a shield-shaped spacecraft could produce an ultravacuum in its wake measuring only 10^{-14} torr—a thousand times cleaner than the environment produced in the best Earthbound chamber.

In 1986, Ignatiev and his team paired up with nine companies to form a Center for the Commercial Development of Space—one of 11 industry-academia partnerships currently supported by NASA. Because CCDS programs have more flexibility than intra-agency ones, the newly formed Space Vacuum Epitaxy Center was able to design and build the craft in one continuous effort, eschewing the interim study phases, development prototypes, and mountains of paperwork that characterize traditional NASA projects. SVEC also kept costs down by using mostly commercial off-the-shelf hardware.

The wake shield's appearance reflects this spirit of economy. It has the look of an industrial castoff, dull silver-gray

On its maiden flight, the Wake Shield Facility had to be kept attached to the shuttle's arm (right), but creator Alex Ignatiev hopes that on subsequent flights the shield will be released so it can create a near-perfect vacuum in which to produce semiconductors. Preparing for a July deployment, Ignatiev wears a suit that minimizes contamination of the shield (left).

A clever new flying factory is exploiting what may be space's richest resource: its emptiness.

Vacuum Cleaner

NASA JOHNSON

DAVID NANCE

It took Ignatiev three months to get his system for growing thin films to work properly in an Earthbound facility, but the setup worked on the first try in space (below: the shield over Lake Winnipeg in Manitoba).

and awkwardly shaped, like a huge saucer bristling with a mélange of tubing, boxes, rods, and assorted electronic equipment. The front, or "ram," side is loaded with avionics and monitoring systems, along with a number of piggybacked experiments studying phenomena such as plasma flow. The back, or "wake," side is where the ultravacuum forms and the semiconductor films are produced (see "Direct Deposit," opposite). Since even a few stray molecules will contaminate the vacuum, the wake side is scrupulously cleaned just before flight, and on the satellite's first orbit the wake side is turned in to the flight direction so that the atomic oxygen present in low Earth orbit can essentially scrub away any residual molecules.

The Wake Shield Facility was sent up for its maiden voyage in February of last year. The original plan was to let it free-fly 40 miles behind the orbiter, but the shield's attitude control system malfunctioned; had it been released in that state, it would have orbited in a slow tumble, which would have prevented a wake vacuum from forming. Mission controllers decided to keep the satellite attached to the shuttle's robotic arm, but unfortunately, the environment near the shuttle is filled with contaminants, and making matters worse, during the flight the shuttle's water release valve leaked. The vacuum the wake shield ended up producing was no better than 10^{-10} torr—about what an Earthbound chamber can achieve.

The mainstream press focused primarily on the failure to free-fly, rather than the scientific and technological results. Those, Ignatiev stresses, are what count. "We still did about 85 percent of what we wanted to do," he says. "We formed a wake vacuum, measured it, and grew crystalline thin films. When we first set up the epitaxial system here in our lab, it took us three months to get it working properly. In space it worked the first time we tried it." Still, he adds, the five gallium arsenide films produced on the flight were only of "nominal terrestrial quality."

"We still have to prove the basic science aspects of the vacuum environment and develop thin-film technology in space," Ignatiev acknowledges. "We want to prove not only that we can make better materials, but in quantities that will make industry take notice."

The semiconductor materials Ignatiev wants to produce in space are far more advanced than silicon, currently the most commonly used material. Like silicon, advanced materials such as gallium arsenide, aluminum gallium arsenide, and indium gallium arsenide conduct electricity with an efficiency between that of conductors (copper, for example) and insulators (e.g., plastic); they can all be tailored to dampen or magnify electrical impulses as needed. But compared to silicon, the advanced materials offer faster electron mobility, more efficient microwave transmission, and lower power consumption. And unlike silicon, many can directly convert electrical impulses to light and light to electricity. Light, of course, moves faster than anything else, and it can also carry a lot more information than electrons can. A computer that uses an "optically active" material like gallium arsenide chips, therefore, would far outperform a conventional model. Advanced materials could also improve the performance of everyday stuff like high-definition TV and cellular phones. Gallium arsenide is already in use as the LED (light-emitting diode) that produces the information-reading laser in compact disc players.

But these compounds are far more expensive to manufacture than silicon, so most American manufacturers have not invested heavily in developing them. Remarking on the wake shield program, technology consultant Joseph A. Saloom notes: "What limits these particular experiments is the development of the [advanced materials] market, which is minuscule compared to silicon." Presently, advanced materials represent less than one percent of the $100 billion-a-year semiconductor industry.

"Everyone wants better materials," says James Ballingall of Martin Marietta Laboratories-Syracuse, which is collaborating in Ignatiev's CCDS, "but this is a long-range, high-risk approach that we would probably not take on [solely] ourselves. Industries these days are much more focused on shorter-range products and problems, watch-

NASA/JOHNSON

ing the bottom line very closely from quarter to quarter. So it's difficult to justify interest in a program like this."

Moreover, terrestrial manufacture is growing more adept at handling what little demand there is for these products. Says John Vaughan, vice president of marketing and business development for the microelectronics division of M/A-COM: "Three or four years ago, a fairly fancy three-inch gallium arsenide epitaxial wafer might have cost $3,000 to $5,000. Today, a four-inch wafer is under $1,000."

Vaughan and others in the industry remain skeptical of space-based manufacturing in general. "People have in their minds that it's got to be more expensive—by a long shot," he says. "It's the shipping costs that all of us believe is the backbreaker. Federal Express doesn't go there." Says Robert Burger, vice president and chief scientist of Semiconductor Research Corporation: "Experiments conducted in space are of almost zero interest to our industry. They address fringe technologies, and no one has ever convinced manufacturers that the results of these experiments will influence in any way the commercial products that they make."

Clearly, if the wake shield is going to catch the attention of the semiconductor industry, it will, at the very least, have to turn in a more impressive performance than the one it gave on its maiden flight. In upcoming deployments, Ignatiev plans to increase the shield's power source by adding solar panels (presently, power is supplied by batteries), thereby increasing manufacturing capacity. He envisions a permanently orbiting wake shield eventually putting out 300 wafers a month, "which in a terrestrial vacuum chamber is damned good." Such a scheme, he adds, would amortize the expense of putting the facility in orbit.

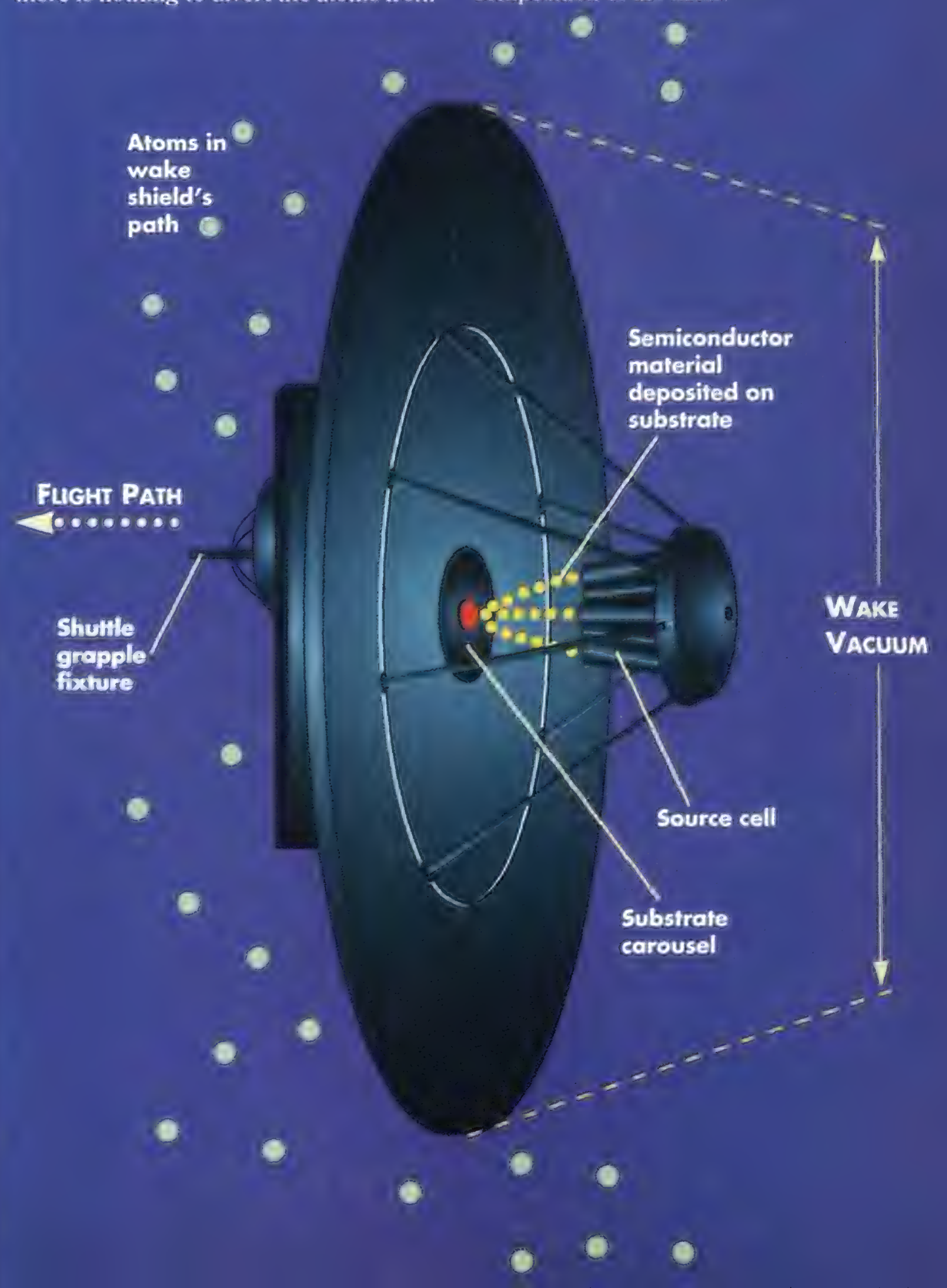
But even if it falls short of Ignatiev's grand design, the shield could have significant spinoffs, serving as a research tool for other disciplines, for example, or driving ground-based vacuum technology in new directions. And if nothing else, the Wake Shield Facility stands as testimony to the undying belief that a universe of opportunity awaits anyone astute enough to tap space's resources—or lack thereof.

Direct Deposit

The source materials used to make the semiconductor films on the Wake Shield Facility are kept in small tube-like furnaces, or cells. The cells are heated to specific temperatures, which enables scientists to control the deposition of the atoms on the substrate. From previous lab work, they know, for example, that if gallium is heated to 2,012 degrees Fahrenheit, the deposition rate will be about one atomic layer per second.

When the materials reach the specified temperatures, shutters at the end of the cells open (for a multi-element compound, such as gallium arsenide, two or more cell shutters open simultaneously). The atoms evaporate toward a carousel holding wafers, or substrates, that will serve as the films' atomic foundations. (In the ultravacuum, there is nothing to divert the atoms from their straight course.) The wafers have been heated to about 1,100 degrees, which induces the atoms striking them to settle into an optimal crystalline structure.

The deposition of atoms in the wake shield is monitored much the way it is in terrestrial labs. Mounted next to the wafers is a gun that fires glancing shots of electrons at the growing films (this does not affect the atoms' configuration). After striking the films, the electrons scatter onto a fluorescent screen, and the resulting pattern of diffraction is recorded by a camera. As each film grows, the pattern's intensity changes. Scientists observing the changes on the ground can transmit instructions to the wake shield that adjust the temperature of the cells or the substrate or alter the shutter openings and closings, thereby changing the growth rate and composition of the films.



GRETCHEN LESSING

THE EAGLES HAVE LANDED

After a quarter-century of teamwork, the best known trio on the airshow circuit is breaking up.

by Henry Scammell

COURTESY CHARLIE HILLARD

EAA ARCHIVES

When the airshow season ends this fall, the longest-flying original team in the history of aerobatics will break up its act after 25 years at the top of a very slippery ladder. In a profession for which the phrase "death defying" could well have been coined, no one, including the Eagles themselves, thought they would last as long as they have.

In 1971, lead pilot Charlie Hillard was the senior member at age 33, Gene Soucy in the second slot was 22, and the third, Tom Poberezny, was 24. The group was formed at the start of that year's airshow season to help raise public awareness—and expense money—for their participation as the American team in the international aerobatic championships to be held in France in 1972. In those days they flew Pitts Specials, a sturdy, single-seat biplane built specifically for aerobatic competition, and called themselves the Red Devils, after the color of their aircraft and as an antonym for the widely known U.S. Navy Blue Angels. All three pilots were civilians, and their state-of-the-art biplanes were fragile dragonflies compared to the Navy's blow-dart F-4 Phantoms. But if there appeared to be any self-mockery in this attempt to define a niche in the airshow marketplace, it vanished the following season when the trio returned from Europe. As a team, they were the world aerobatic champions. And Charlie Hillard was named Overall Absolute world champion.

The Red Devils lasted only eight years. The catalyst for their transformation into the Eagles was a racy aerobatic prototype provided by Frank Christensen, a former aerobatic champion who had managed the American team at the 1972 sweep in France. In 1978, Soucy flew this craft, the Christen Eagle I, to a third-place finish in the national aerobatic contest, and the following year the team changed their airplanes and their name. Christensen saw in the trio a vast potential for promotion of his kit-built aircraft and recruited the whole team. "They were the three best-known pilots around," he recalls. "I offered them an image."

In addition to the new name, Christensen's image for the team included orange jumpsuits emblazoned with the same rainbow motif that adorned the airplanes, plus advertising and promotion. He also took full responsibility for maintenance of the aircraft, paid a portion of the team's expenses, and allowed the pilots to keep all of their airshow earnings, which in a good year might total some $50,000 each.

After five years, however, Christensen concluded that the market for his aircraft was too small to enable him to maintain his initial level of support, so he sold the team's airplanes to the three pilots. The Eagles began looking for another sponsor.

They didn't have to look far. AVEMCO Insurance, the largest underwriter in general aviation, was quick to realize the team's marketing potential. "Insurance companies underwrite risk, but risk is the last thing they want to promote," says CEO William Condon, himself a pilot. "We looked at every act in the business, and the Eagles were by far the

Before teaming up to take center stage on the airshow circuit as the Red Devils (left), each of the individual players had already made a name for himself. Insets, left to right: Charlie Hillard was a skydiving champion and an aerobatic competitor; Tom Poberezny, shown with father Paul, was born into the Royal Family of sport aviation; and Gene Soucy was a veteran airshow performer who hooked up with Poberezny in 1968. Three years later, the trio, flying Pitts Specials, opened to rave reviews (below and bottom).

three brightest stars in the sky. For us, the appeal isn't that the Eagles are taking terrible chances but because they're so incredibly focused and precise that the risk is nearly zero. And that's the message they're selling in our marketplace."

But AVEMCO's marketplace doesn't include the general public, and the non-flying majority of an airshow audience probably has a far simpler view of the Eagles: as inhumanly skilled, irrationally fearless, and supernaturally lucky. To the uninitiated, the progression of maneuvers—from the snap roll on takeoff, through formation barrel rolls and lazy eights, loops and hammerheads, and up-and-down bomb bursts, to the switchblade and torque roll and the double snap rolls at landing—is a pyramid of breathtaking improbabilities for which the term "aerobatic safety" seems nearly an oxymoron.

Charlie Hillard has been doing this for the fun of it since 1958, and he is quick to point out that the decision to retire the team doesn't mean that any one of the Eagles has abandoned his commitment to the sport or is getting out of the business. "But it's taken away a little bit of the fun during the past two years with the hassle of all three of us trying to coordinate with each others' lives," he says. "I've enjoyed what we do, and I'm still going to fly some shows—on my own schedule." To that end he's restoring a de Havilland Sea Fury. "I know that Gene would love to continue flying and keep the team together," he says. "But Tommy and I have so many other responsibilities, it seemed 25 years was a good point to finish. That's a long time for three people."

No one has had closer professional contact with the team than Christensen. "I probably have more insight into their personalities as pilots than anyone," he says. "They used to come out to California and stay at my ranch for weeks at a time."

Of the three, Hillard quickly emerged as the leader. "He is the oldest, had been flying the longest, while the other two were still youngsters," Christensen says. "But he was more intellectual than physical as a pilot, analyzing the contests and maneuvers and figuring what had to be done, and he worked hard for what he got. Even now, Charlie is still the sort of distant one, the one you can't get close to too easily; probably the most discerning, analytical, and least animated of the three."

Christensen calls Soucy an "instinctively pure, natural pilot. Like Barbra Streisand, he had the voice and it came easy," he says. "If he had never been taught to fly, he would still be able to fly; he just understands what airplanes do by the way they feel when you get into them. And he cannot possibly get enough of it; airplanes and flying and aerobatics are just like a special gene in his system. He started out as a kid and gets essentially all of his self-esteem from it. He'll still be flying airshows when he's 75."

Poberezny, Christensen says, is "well educated, diplomatic, refined, skilled with people and skilled at putting things together. When he started flying, people tended to write him off because he came from such a big name, the family that had founded the EAA [Experimental Aircraft Association]—but anyone who looked closely could see that he was every bit as good a pilot as the other two. Even when he won the national championship and was ranked in the world, he didn't get the same recognition as a pilot as he got for being the son of Paul Poberezny. Now, of course, people realize that Tom's management skills with EAA far exceed those of his father, and those who know what they're looking at give him the credit he deserves as a pilot."

The year after the Red Devils started, psychologist Bruce Ogilvie and physician-aerobatic pilot Champe Pool published a preliminary report on "Motivation of Aerobatic Pilots" in the Experimental Aircraft Association monthly, *Sport Aviation*. Based on the answers to some 1,350 questions posed to aerobatic fliers, the survey concluded that: "Aerobatic pilots may be the most cool, reserved, critical, and emotionally detached of any athletic group we have tested to date....

EAA ARCHIVES (2)

[S]uccessful aerobatic competitors are ambitious, organized, autonomous individuals who have unusual capacity to apply themselves over long periods of time. They are not especially 'giving' people, nor are they particularly interested in others.... They certainly are the introverts of the athletic world, they retreat very much from...the gregarious way of life, they are abstract, oriented, creative people who have a high level of self-sufficiency."

The Eagles may be more dissimilar than they are alike in other respects, but all three are quick to own up to almost every one of the qualities in the Ogilvie-Pool profile. None sees any inconsistency between those traits and the team's record as the longest-lived and perhaps the most tightly integrated in the history of the sport. "Aerobatic pilots are intense individuals, so it's a little unusual to get three guys that are such diverse personalities," Hillard acknowledges. "But the way we got together was we were competing fiercely against each other, and we were all proud of our precision. We're just as proud of it as a team. There's really a lot of satisfaction in knowing you're doing a bang-up show."

The son of a Fort Worth auto dealer, Charlie Hillard soloed at 16 and two years later bought a clipped-wing Piper Cub that had belonged to legendary aerobatic champion Bevo Howard. Hillard got out of airplanes just long enough to become a national skydiving champion while a student at Georgia Tech; following a jump-related shoulder injury, he attended college in Texas, already a veteran airshow pilot and fledgling aerobatic competitor.

By the time of his 1972 triumph in France, Hillard had spent nearly half his life in pursuit of that transforming moment. "Winning the world championships and what they call

CHRISTEN INDUSTRIES

Buyers of the Christen Eagle II got 28 tidy kits and construction manuals with "detailed instructions and simplified illustrations."

The Christen Eagle

Frank Christensen, 1969 national aerobatic champion and manager of the winning U.S. team in France in 1972, gave the Red Devils a one-of-a-kind aerobatic aircraft. Based on the Pitts Special, the Christen Eagle I was stronger, more powerful, and slightly faster than its descendant, the Eagle II kitplane version that was sold to homebuilders. The Eagle I was nearly 30 percent heavier than its major rival, the 1,150-pound Pitts Special S-1S, but it featured a 260-horsepower Lycoming engine as compared to the Pitts' 180, giving the two aircraft the same climb rate: 2,600 feet per minute. The Eagle's extra weight translated to structural strength: It was built to pull 9 Gs positive and 6 Gs negative versus the standard +6 and -3.

The Pitts and Eagle also had a couple of features in common. Both used fixed-pitch propellers, which operate at a higher RPM than constant-speed props and produce the kind of feral rasp favored by airshow audiences. (Propellers are airfoils, and the drawback to a fixed-pitch propeller is that its blade angles cannot change. The blade angle of a constant-speed prop changes with conditions to produce the most efficient performance during takeoff, climb, and cruise.) And each employed a Christensen innovation: the Christen 801 oil system, which supplied positive pressure in any attitude, allowing unlimited inverted flight.

DEKEVIN THORNTON/EAA

the Overall Absolute was one of the high points of my life," he says, "and I worked real hard to get there. It had become an obsession." He had been flying professionally for a decade when he entered his first international competition, in the Soviet Union in 1966, and he placed in the cellar at 29th. Two years later, in East Germany, he leapt almost two-thirds of the way up the ladder to 11th. In England in 1970 he placed third.

If there was a clincher to Hillard's victory in France, it was his introduction in the freestyle competition of a spectacular maneuver in which the airplane roars straight upward until it is hanging on its propeller, then begins to rotate about its longitudinal axis in slow corkscrews, driven by the twisting power, or torque, of its engine. Since then the torque roll has become one of Hillard's—and the Eagles'—signatures, as well as a widely copied standard in competitions and performances.

After France, Hillard maintained a rigorous airshow schedule with the Red Devils, but he competed for only one more championship, the 1979 nationals, and that was 12 years after winning his first national title. "I was too busy to practice," Hillard recalls, "and I knew I was in trouble going in; it was a half-hearted effort." He finished an unlucky 13th.

Aerobatics is not a poor man's sport; for Hillard, the principal distraction at the time of that last contest was not from his flying but from the business that sustained it. Some years before he had gone into automobile leasing, accumulating a string of car rental franchises in the Dallas-Fort Worth area. He eventually sold these and joined his father's car dealership as manager. Instead of training as hard for that final championship as he had for earlier competitions, Hillard's priorities were on the ground, minding the store.

While the demands on Hillard's time were increasing from his business, so were his responsibilities as Air Boss at Oshkosh, where the annual fly-in, which started as a small gathering of kit-builders, has grown to a yearly invasion of some 12,000 airplanes and 850,000 visitors. But the biggest change has been in the priority Hillard now places on his family.

Hillard's first marriage was sacrificed to his self-described obsession with flying. Thirteen years ago Hillard married again, this time the daughter of a Michigan airport manager. In addition to gassing airplanes, answering the radio, and learning to fly, Doreen grew up loving the outdoors. Hillard's wedding present to his new wife was a Piper Clipper. As a child, she had helped her father assemble the airplane from three others; with Poberezny's help Hillard had located it and had it restored.

Hillard may be the lone Eagle, but Tom Poberezny and Gene Soucy have been flying together since they met at an airshow in Aurora, Illinois, in 1968. The two were joined at the hip in the initial years of their friendship: Soucy

All three Eagles have found that an airshow pilot's career is a demanding one, particularly when it must be juggled with a "real" job and a family. "There's a side of me that's going to cry to see the Eagles era end, because I know it's his first love," says Sharon Poberezny (below, at right, with Doreen Hillard). "There's another side that wants him home more."

JIM KOEPNICK/EAA

ERIK HILDEBRANDT

married Poberezny's sister Bonnie, Poberezny flew a Pitts that belonged to Soucy's father, and the teammates paced each other for the better part of a decade in aerobatic competitions.

Unlike Hillard, the two younger Eagles were born into the profession. Poberezny's father, Paul, founded the Experimental Aircraft Association in his cellar in 1953 as a gathering place for people who wanted to trade information about building their own airplanes. Soucy's parents, both flight instructors and also established figures on the airshow circuit, were part of the same tradition. Soucy soloed in a glider at age 14 and under power two years later. By the time he became a flight instructor at 18 he was already a veteran airshow performer and well on his way to a string of national championships.

By pedigree, environment, and tradition, Poberezny would have seemed the likeliest of candidates to leap into the air at the first chance. "Everybody expected…the typical story of a kid who grows up and can't wait to follow in his father's footsteps," he says. "But because flying was always there and always available, I tended to look past it until I was ready to balance it against my other activities." He didn't get around to earning his pilot's license until he was 18.

Though they will no longer fly as a team, the Eagles will remain part of what Soucy calls the airshow family (below), with Hillard as Oshkosh Air Boss and de Havilland Sea Fury show pilot, Poberezny as head of the EAA (below right), and Soucy an aerobatic competitor, solo act, and performer with wingwalker Teresa Stokes.

Soucy had several years more flying experience and was distinctly the mentor at the beginning of their friendship. The year after the American victory in France, that all changed. "When Tom won the U.S. Aerobatic Championship of 1973, he took it away from Gene," says Poberezny's wife Sharon, "even though Gene had been his teacher."

Poberezny's winning of the national championship had brought him closer to parity with Soucy in one area, but there were other, more subtle ways in which their lives were slowly beginning to diverge. In 1974, in order to support his show habit, Soucy started flying for North Central Airlines. Over the years he worked his way up the seniority list and is now a captain with Northwest. "I was doing these airshows and just had to get a job," he says. "I stay senior captain in the DC-9 so I can get weekends off to do this. I fly three shows a month."

Where Poberezny's life as president of the EAA since his father's retirement in 1989 is inextricably linked with family, Soucy, who has been married and divorced twice, has seen flying negatively affect his. When asked if his life as an airshow pilot is hard on marriages, he replies with deadpan geniality, "Must have been." A moment later he adds, "I'm sure that was the problem. My second wife said, 'You're not going to change, are you? You're going to keep flying those airplanes.' I said, 'Of course I am.' I guess she thought I'd get out of it." But, as Christensen says, this Eagle is wed to the airshow circuit. "It's so small, all aviation is like a family," Soucy says. "You come to this event and it's a family reunion. I go home and I don't know anybody. These people are my friends. I've been traveling all my life. This is my family."

EAA

ERIK HILDEBRANDT (2)

Today, along with a decreasing number of performances as an Eagle, Soucy flies a wingwalker act in a red and yellow Showcat, a modified Grumman Ag Cat biplane. For the past six years the act has featured the athletic, diminutive, and apparently fearless Teresa Stokes, one of the biggest names in a profession whose members can be counted on two hands.

There is yet another ring in the Soucy circus. He also frequently performs a solo act in the German-built aerobatic Extra 300S, an airplane in which he eventually plans to return to national competition. "As long as I do some kind of an airshow," he says, "I'm happy."

EAGLE ARCHIVES

"Any time you fly close to the ground and you're going fast, you really feel the speed; we're flying airplanes that climb 1,400 feet in 20 seconds, and that kind of performance is pretty exhilarating," Hillard said just after their act at Oshkosh last summer. He touched the wing of his airplane and watched absently as a white glider looped through the sky to the refrain of "Born Free," piloted by a performer 20 years his senior who learned to fly in the 1940s.

"The older I get, the more I realize how much I really do love to fly," he continued. "I look at a guy like Bob Hoover, who has absolutely lived for flying all his life and then all of a sudden he loses his medical [certificate], and I start thinking something like that could happen to any one of us. I think that's another reason I want to quit at 25 years. I'll be 57 and I feel as good and capable as I did 25 years ago. I want to have that feeling when we quit, and I want Tommy and Gene to have it too."

Poberezny voices some concerns about the next generation of airshow pilots and the increasingly competitive environment they will fly in. "The better pilots are those who can execute professionally with the highest level of precision and still be entertaining," he says. "They don't have to fly the lowest or on the edge all the time, because they're more creative.... Today we live in a marketing society, and it seems that people who depend on the public spotlight have to be controversial or flashy to make an impact or just to stay where they are. I have the feeling that the airshow business is going more that way. A lot of people are trying to get in and make as big an impact as possible, and they're not going to wait 15 or 20 years—they just go buy an airplane and want to be a top professional quick."

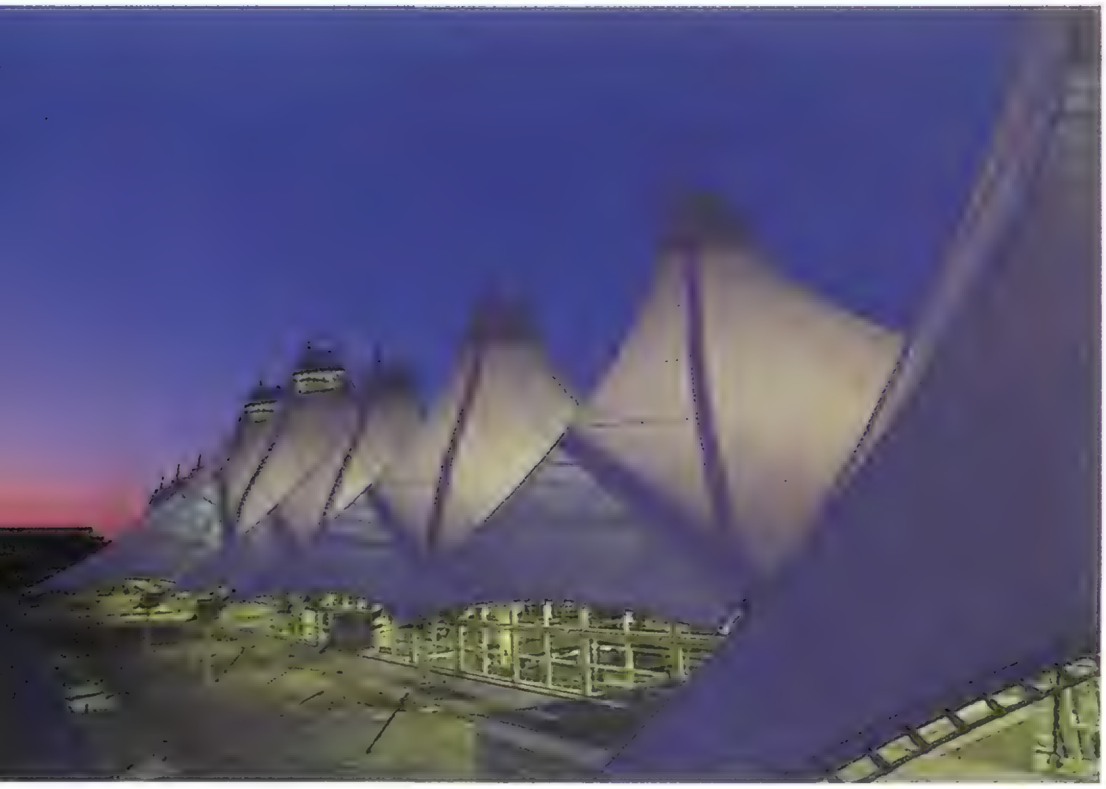
If the biggest part of their lives together is coming to an end, many of the things that bound them at the start remain intact, and they will doubtless be seeing a lot of one another—Poberezny with the EAA, Hillard as Air Boss at Oshkosh and as a future competitor, and Soucy with his wingwalker, new solo act, and as a future contestant in the national championships.

"I love to fly airshows, and it's absolutely been one of the biggest parts of my life," says Hillard. "But I had as much fun last week fishing in a remote section of British Columbia as I've ever had flying airshows. And flying in to a 5,000-foot [altitude] lake where you know if you make any mistake at all you're going to spend the rest of your life there—and then catching a 24-inch rainbow trout and cooking it! To me that's as much adventure as flying a show."

After a long reign as "the three brightest stars in the sky," as the team's sponsor calls them, Poberezny, Soucy, and Hillard (below, left to right) found that breaking up was hard to do. But, as Hillard points out, "It seemed 25 years was a good point to finish. That's a long time for three people."

JIM KOEPNICK EAA

>SIGHTINGS<



ERIC SANDER (LEFT); RICHARD SHOCK (RIGHT)

Well, it was certainly pleasing aesthetically, with the Teflon-coated fiberglass roof of the terminal building mimicking the snow-capped Rocky Mountains. But until Denver International Airport opened on February 28, it threatened to replace airline food as the main butt of industry jokes. The airport opened 16 months behind schedule and more than $3 billion over budget, with some much-publicized difficulties stemming from a balky computer-controlled baggage system. On opening day even the baggage system functioned, although only United Airlines used it (other airlines used a backup manual system). An uncooperative jetway did delay the first arriving flight, which had to be towed to an adjacent gate.

With three parallel runways able to handle simultaneous landings, the new airport is supposed to make the bad-weather bottlenecks of the old Stapleton facility a thing of the past. Despite a snowstorm on opening day, DIA appeared to live up to its promise. And it looks swell too.

Barnstorming With Roscoe and Gilmore

B.F. PARISH

Roscoe Turner: Aviation's Master Showman *by Carroll V. Glines (foreword by James H. "Jimmy" Doolittle). Smithsonian Institution Press, 1995. 368 pp., b&w photos, $29.95 (hardcover).*

Among the dozens of photographs that illustrate this well-crafted biography, perhaps it's the very first image that is most telling: A very young Roscoe Turner and his brother stand behind a team of mules hitched to a plow in a Mississippi field. The old black-and-white photograph prompts one to wonder how many other pilots of the Golden Age of Aviation (the 1920s and 1930s) owed their wings to a view of the world from behind a team of mules straining under a hot sun. In this ably written biography, Carroll Glines treats us to many such details, which bring to life a truly fascinating aviation career.

Turner recognized early on that the creation of a "legend" would help him further not only his own ends but, from a practical standpoint, those of aviation as well. Even during his early days as a barnstormer, Turner was promoting the benefits of aviation (and aviation safety) to the public while at the same time struggling to make a living. Turner's pet lion, Gilmore, was probably his best known promotional gimmick, but Glines notes that the lion was much more than a gimmick to the pilot, and indeed the two enjoyed many adventures together.

In addition to his pet lion, Turner was famous for wearing a uniform. This custom was based on the commonsense observations that a uniform commanded respect, that it was suitable for both day-to-day flying operations and formal occasions, and that grease-spattered coveralls did nothing to promote aviation. In fact, in 1918 Turner had been commissioned as a second lieutenant in the Aviation Section of the Signal Corps Reserve—not as a fixed-wing pilot but rather as a balloon observer. He served briefly in France in World War I. The "Colonel," a title he almost invariably assumed in public and the media, came later as an honorific from the governors of Nevada and California, both of whom he served as a highly regarded personal pilot.

Roscoe Turner could only have happened in America. His career was a classic rags-to-riches epic, and one can only wonder how many youngsters were influenced by his example during the dark days of the Depression. With this book, Carroll Glines makes that sort of influence possible all over again. I hope copies find their way onto library shelves across the country.

—Dan Hagedorn works in the archives division at the National Air and Space Museum. He is co-author (with Leif Hellström) of Foreign Invaders: The Douglas Invader in Foreign Military and U.S. Clandestine Service *(Midland, 1994).*

Skygods: The Fall of Pan Am *by Robert Gandt. William Morrow, 1995. 317 pp., b&w photos, $23.00 (hardcover).*

This lively, highly readable, and by turns tragic, comic, nostalgic, and horrific story of the slow death of the airline that promised us the moon begins with a familiar disclaimer: "In certain instances the names have been altered for reasons that will be apparent to the reader." They're apparent all right—from the pilot who calls home from Rio and talks with his dog to the Clipper captain whose showboat approach catches a wingtip in Lisbon Harbor and kills most of his passengers. In fact, it's hard to imagine the book being written in its present form if all of the principals, including Pan Am itself, were still alive.

The skygods of the title are mainly the Pan Am captains, some of whose careers began in the earliest days of the flying boats and ended up in the cockpits of 747s. They include the airline's founder, Juan Trippe, its principal pathfinders, Charles Lindbergh and Edwin Musick, and a colorful gallery of successors to the presidency who fought to keep aloft an enterprise that Gandt feels was doomed from the day in May 1968 when Trippe handed over the controls to a dying Harold Grey.

To supplement his own experience and insights, Gandt (a 26-year veteran Pan Am pilot) polled some 200 Pan Am alumni, the great majority of them fellow pilots, and wove their colorful recollections into a storyline that follows the corporate descent from the airline's apogee in the mid-1960s to its literal and symbolic wreckage in the aftermath of a terrorist bombing over Scotland. Whether you fly in the front of the airplane or in the back, this story by and about pilots is as close as you can get to being there. But just about the only place you'll see a reference to

passengers as anything but numbers is in a chilling tableau near the end—in treetops, on lawns, and the front yards of Lockerbie.

—Frequent contributor Henry Scammell wrote about Pan Am in the Apr./May 1986 and Aug./Sept. 1989 issues.

CURATOR'S CHOICE

Lockheed's Skunk Works: The First Fifty Years *by Jay Miller. Aerofax, 1993. 216 pp., b&w and color photos, $29.95 (paperback).*

This work combines research based on unprecedented access to the archives of America's most secret and successful aircraft company with the skill of an outstanding technical aviation writer. The result is a benchmark in aviation publishing. From the Skunk Works' beginning 50 years ago to the aircraft the company may one day produce, Jay Miller covers it all in amazing detail. He brings to print aspects of America's "black world" aircraft that even serious aviation buffs have never seen. The book includes an excellent photo selection, from the XP-80 to the YF-22 and every Skunk Works creation that flew in between.

—Thomas M. Alison is curator of the military aircraft collection at the National Air and Space Museum.

Tailspin: Women at War in the Wake of Tailhook *by Jean Zimmerman. Doubleday, 1995. 416 pp., b&w photos, $24.95 (hardcover).*

If you care about naval aviation, read this book. But be warned: *Tailspin* is not for prudes. This is the definitive account of the Tailhook scandal, when at least 26 military and civilian women were groped, stripped, and even bitten while attempting to make their way past the "gauntlet" in a hallway of the Las Vegas Hilton during the September 1991 annual convention of the Tailhook association of naval aviators. Jean Zimmerman's gritty description of the third-floor party suites, where bodies were "slicked up in the heat like seals" and the carpet was squishy with brewed and spewed substances, captures both the terror of the women who found themselves in the gauntlet and the insular attitudes of the men involved. Victim blaming—the old "she asked for it" mentality—was strong, as demonstrated by one rear admiral's comment that any woman who cussed as much as helicopter

pilot Paula Coughlin (the first military woman to bring charges) "would welcome this kind of activity."

Zimmerman interweaves the history of women's integration into the Navy with the story of Tailhook 91's progression from event to scandal, investigations, and trials. She sets time-honored naval rituals (which Winston Churchill disparagingly described as "rum, sodomy, and the lash") against modern variants like the "binge and purge" party mentality of naval aviators. Although the author clearly supports women in the military, she includes opposing opinions as well.

Just how smoothly is gender integration going in the Navy? One female aviator told Zimmerman she "felt she was always being made to try out for the team—even after she supposedly made it." Another woman pilot addressed male concerns about unit cohesion: "Basically what they're saying is that they can't perform when there's a woman in their squadron…if you can't handle that…then you don't belong in combat. Because being in combat is a lot more stressful than just having a woman on your wing." In *Tailspin*, Zimmerman pulls no punches in detailing both the failures and successes of the Navy, and she shows the relationship between attitudes toward women in the service and the sort of harassment that erupted at Tailhook 91. *Tailspin* is absorbing, provocative, fast-paced, and must reading for anyone concerned about today's military.

—Reina Pennington, a former Air Force intelligence officer, wrote "Wings, Women, and War" in the Dec. 1993/Jan. 1994 issue.

My War *by Andy Rooney. Times Books, 1995. 318 pp., b&w photos, $25.00 (hardcover).*

From 1942 to 1944, airmen in England knew Andy Rooney as a *Stars and Stripes* reporter who, along with Walter Cronkite and Homer Bigart, flew beside the crews on their missions. Besides depicting their bravery against flak and fighters, Rooney's writing was distinguished by its recognition of the strain involved in waiting for the next mission.

Fifty years later, the former buck sergeant, now resident curmudgeon on "60 Minutes," has written a book about that time. After briefly describing

his pre-war years, he begans this memoir with the air war against Germany. Rooney was never far from the action, and he has an Air Medal, a Bronze Star, and a surrendering German officer's pistol to prove it. He doesn't flinch from describing war's violent and gritty aspects. When he entered Buchenwald, what he saw there forever convinced him that "any peace is not better than any war." Yet he also has a more sentimental view of war. He loved his Eisenhower jacket (the "fashion smash" of the time) and leather bomber jacket ("with the 306th Bomb Group insignia"), and he got so attached to his jeep ("one of the great inventions of the war") that he made sure to leave it with a good owner.

Rooney doesn't hesitate to assign individuals and events to their place in history. He writes about D-Day: "There have been only a handful of days since the beginning of time in which the direction the world was taking has been changed for the better by an act of man. June 6, 1944, was one of them." The Eighth Air Force he describes as "one of the great fighting forces in all the history of warfare." And the B-17 bomber he says "did more than any other airplane to win the war."

He also writes about legendary figures. Eisenhower is described as "somehow lovable, being, at the same time, competent and bumbling." Rooney has nothing but contempt for George Patton, "a loud-mouthed boor who got too many American soldiers killed for the sake of enhancing his own reputation."

Rooney's anecdotal support of these opinions makes good reading. With over 6,000 books already published about World War II, the former *Stars and Stripes* reporter still manages to find something new to say in *My War*.

—Harry H. Crosby, former director of the Writing Center at Harvard University, wrote A Wing and a Prayer *(HarperCollins, 1994) about his experiences as an Eighth Air Force group navigator.*

FYI

Written for young women preparing for a career in astronomy or astrophysics, *Space for Women: Perspectives on Careers in Science* is full of advice on coursework, choosing colleges, and finding mentors. The booklet can be obtained by writing to the Publications Department, Harvard-Smithsonian Center for Astrophysics, MS-28, 60 Garden Street, Cambridge, MA 02138, or calling (617) 495-7461.

CREDITS

The Long Way Home. In the 28 years he flew for Pan American Airways, John A. Marshall Jr. never flew as long a flight as Captain Robert Ford's. Today he flies for Korean Air Lines and writes about early commercial aviation from his home in Idaho.

The Man in the Homburg Hat. Still flying at age 72, Ben L. Brown has piloted over 150 military and civilian aircraft.

Death of the Beast. Ralph F. Wetterhahn flew combat tours during the Vietnam war for both the Air Force and the Navy. He spent more than seven years in Asia.

After watching B-52s being summarily dispatched, Los Angeles-based photographer Chad Slattery hopes that there is an afterlife for good airplanes.

Go With the Flow. Stephan Wilkinson is a contributing editor of *Air & Space/ Smithsonian.*

Web Bryant was part of the design team that created *USA Today.* His first love, however, is painting, especially when he can work with natural and directional light.

Mapping the Milky Way. Donald Goldsmith's books include *The Astronomers, Supernova!,* and *Nemesis.* In 1990 he was awarded the Lifetime Achievement Award by the Astronomical Society of the Pacific.

"Houston, We Have a Movie." Henry S.F. Cooper Jr. is the author of eight books about the space program, including *13: The Flight That Failed,* which the director, actors, and screenwriters for *Apollo 13* read to prepare for the film. The book was reissued this spring by Johns Hopkins University Press.

The MiGs of the Luftwaffe. Steve Vogel is a reporter for the *Washington Post.*

Mark Simon is an American photojournalist living in Berlin.

To Make a Vacuum Cleaner. Frequent contributor Frank Kuznik is a freelance writer based in Washington, D.C.

The Eagles Have Landed. When Henry Scammell isn't at an airshow, he writes about art, business, murder, and medicine.

Inside the Red Zone. William Triplett visited the National Aviation and Space Museum while in Russia researching "Dreams for Sale" (Dec. 1994/Jan. 1995).

CALENDAR

June 2–4
Bucks County Balloon and Air Festival. This all-female airshow includes performances by Patty Wagstaff and Julie Clark. Quakertown Airport, PA, (215) 997-9519.

June 3 & 4
World War II Commemorative Weekend. Mid-Atlantic Air Museum, Reading, PA, (610) 372-7333.

June 9–11
Aerodrome Days 95. Kansas Aviation Museum, Wichita, KS, (316) 683-9242.

June 10 & 11
"High on America Air Show." Kalamazoo/Battle Creek International Airport, MI, (616) 381-8237.

June 16–18
Aerospace America International Airshow. Will Rogers World Airport, Oklahoma City, OK, (405) 236-5000.

June 17 &18
EAA Chapter 723 Fly-In. Camarillo Airport, CA, (805) 488-3372.

June 24 & 25
EAA Chapter 36 Fly-In. Potomac Airpark, Berkeley Springs, WV, (717) 294-3221.

New England Regional Fly-In. Orange Municipal Airport, MA, (508) 544-2212.

June 29–July 2
PB4Y All Squadron Reunion. Arlington, VA, (510) 487-PB4Y.

July 4
Rockport-Fulton Air Show. Aransas County Airport, Rockport, TX, (800) 242-0071.

July 12–15
Warbird Formation Flying Clinic. Watch T-6s, T-34s, T-28s, and P-51s practice formation flying. Greenwood, MS, (601) 453-5646.

July 14–16
Norseman Float Plane Festival. Red Lake. Ontario. Canada. (807) 727-2809.

July 15 & 16
Upper Midwest EAA Fly-In. Regional Airport. Casselton, ND, (701) 293-0778.

July 18–22
Airliners International Convention. Buy, sell, and trade aviation collectibles. Camelback Inn, Scottsdale, AZ, (602) 993-8276.

"The Satellite Sky" Update/48

These regular updates to "The Satellite Sky" chart will enable readers to keep their charts up to date. Additions can be clipped and affixed to the chart at the appropriate altitude.

New launches

90 to 300 MILES

- Cosmos 2306 — 3-2-95 PL
- Soyuz TM-21 — 3-14-95 TT
- Cosmos 2311 — 3-22-95 PL
- Progress M-27 — 4-9-95 TT
- Space Flyer Un — 3-18-95 TAN

300 to 630 MILES

- Cosmos 2310 — 3-22-95 PL
- DMSP — 3-24-95 VAFB
- Orbcomm 1&2 — 4-3-95 Pegasus
- Microlab 1 — 4-3-95 Pegasus
- Offeq-3 — 4-5-95 PAL

6,200 to 13,700 MILES

- Cosmos 2307-9 — 3-7-95 TT

21,750 to 22,370 MILES

- Intelsat 705 — 3-22-95 CAC
- Brasilsat B2 — 3-28-95 KOU
- Hot Bird 1 — 3-28-95 KOU
- GMS-5 — 3-18-95 TAN

Deletions

90 to 300 MILES

Bremsat down 2-12-95
Cosmos 2280 down 3-10-95
Soyuz TM-20 down 3-22-95
Progress M-25 down 2-16-95

Launched but not in orbit

90 to 300 MILES

Foton 10 CIS research	2-16-95	down 3-3-95
Progress M-26 CIS research	2-15-95	down 3-15-95
STS-67 U.S. research	3-2-95	down 3-18-95

Inoperative but still in orbit

90 to 300 MILES
Cosmos 2244

300 to 630 MILES
Cosmos 2123

21,750 to 22,370 MILES
Cosmos 1961
PRC 41
Telstar 3A

DATA: SAUNDERS KRAMER

FORECAST

In the Wings...

The Last Raid. The atomic bombs that fell on Hiroshima and Nagasaki 50 years ago this August began a new era of history, but they did not end the war. While the enemy continued to resist surrender, every airworthy B-29 in the Pacific was launched against Japan.

A Rock From a Hard Place. While engineers and scientists were working on ways to get to Mars, a little piece of Mars came to Earth.

The Woodstock of Skydiving. What do a de Havilland Super Twin Otter, a Lockheed Constellation, a Stearman biplane, a Bell LongRanger helicopter, and a blimp have in common? They're all jump platforms at the annual World Freefall Convention in Quincy, Illinois.

Astronomical Buddy System. Astronomy can be a fiercely competitive science, but whenever something big happens in the sky—a comet slamming into a planet, for example—an astronomer's competitive drive is overtaken by the need to network.

JOHN HEINLY

Inside the Red Zone

"This is Su-15," says Gennady Roshchin, pointing to the long, narrow Sukhoi fighter that was once a staple of the Soviet air force. "It was this type jet that shot down Korean Air Lines 747." In fact, he elaborates, when a Russian movie was made about the 1983 downing of flight 007, this very jet was used in the filming.

Roshchin moves down the line. "This is Su-25," he says, pointing to a ground-attack jet with rocket pods and dummy bombs hung from the wings. "This saw very much action in Afghanistan."

He walks on, continuing with the same authoritative dispassion one hears in the voices of museum guides the world over. But it would be impossible to mistake Roshchin for anything other than a Russian. He is a retired Soviet fighter pilot who will say of his past only that he turned in his flightsuit long ago (press him for specifics and he will graciously evade the question). The museum where he serves as deputy director—the National Aviation and Space Museum, a.k.a. the National Aeronautics Museum or the Museum of the Air Forces—eschews the standard early artifacts found in most collections in favor of more contemporary models, particularly tactical combat aircraft. Indeed, the more than 30 aircraft on view represent the bulk of Soviet fighters built over the last 40 years.

The collection is located among Moscow's northern suburbs at the old Central Aerodrome at Khodinka field, which is something like the Wright air field of Soviet aviation. It was there in 1910 that B. Rossinsky became the first Russian to fly an airplane. The field was the site of another flying triumph the following year, when Russian pilot Alexander Vasiliev landed his Blériot XI there, the only one of 11 pilots to finish a grueling 453-mile race from St. Petersburg to Moscow. Design bureaus for Sukhoi, Mikoyan Gurevich (MiG), Ilyushin, and Yakovlev are all in the neighborhood, as is the main headquarters of Aeroflot and the Russian version of the Federal Aviation Administration.

Roshchin says that the museum got started four years ago, when a group of former Soviet pilots decided to pay homage to their nation's aviation history. They managed to put a collection together out of donations, a tradition they hope to continue. They also hope to keep some of the aircraft in good enough condition to fly occasionally, and they're planning to develop an exchange program with similar museums in the West.

The aircraft are all parked outdoors, flanking the sides of an old taxiway, so you can admire, say, the red-starred twin tails of a MiG-29 or Su-27 against the backdrop of the Moscow skyline. Of course the craft, constantly exposed to the elements, are beginning to show signs of wear and tear, but by and large everything is in good viewing condition. The collection includes some appealing oddities—there's a virtually wingless Yak-38 vertical-takeoff-and-landing aircraft, as well as an Mi-6 helicopter you can party in: The payload hold, its walls draped with parachute cloth, has been furnished with a table and chairs. "Anybody with bottles is welcome," says Roshchin.

Among the few propeller-driven airplanes in the collection is an Il-14, which served as both a cargo plane for the military and a passenger transport for Aeroflot during the 1950s. Like the payload hold of the Mi-6, the cabin of the twin-engine airplane has been reconfigured for socializing. An oriental rug covers most of the floor, a sofa is set against one wall, a table is pushed up against another, and a well-stocked bar with a radio has been built along the cockpit bulkhead. Two small flags—one American, one Russian—protrude from the spent casing of an anti-aircraft shell. The Il-14 is decorated with photographs of large Soviet bombers and transports, which can't be flown to the aerodrome because its runway is too short.

In some ways, the museum reflects the Russians' struggle to find any means to survive a wrecked economy. Roshchin recently doubled the price of admission, and it'll cost you another buck if you want to take pictures. Just as the Russian aerospace industry is selling other nations everything from missiles to fighters, the museum's souvenir shop—essentially an old closet—is stocked with everything from flight patches and lapel pins to oxygen masks and uniform coats, all Soviet-era, all for sale at a negotiable price. Ironically, war materiel that was once used in the fight against capitalism is now enlisted in the effort to bring in capital.

"I also have shells from when Yeltsin fired tanks at White House," Roshchin says, referring to the 1993 siege of Russia's parliament. "They make very good candle holders."

"Actually, I was interested in a Soviet flight jacket," says an American visitor.

"What size?" He gets it in a day with no problem.

Despite his widening entrepreneurial streak, Gennady Roshchin is hardly about to become the Sam Walton of Soviet aviation. He does no advertising, and he's not interested in tracking the demographics of his visitors (he thinks they are primarily families with young children, but he's never really paid much attention). "I believe boys really have a good time here," he says. Today there are maybe two families roaming the sprawling grounds—not an unusual day, he says.

Roshchin is well versed in the history of each aircraft displayed; you get the feeling he would much rather spend hours talking with one truly curious visitor about the MiG-17 or the Su-7 than give tours to a dozen families just passing through.

"I am retired," he says with a shrug. "This is my playground."

—William Triplett

National Aviation and Space Museum, 24a Leningradsky Prospekt, Moscow, 125040, Russia. Phone (7095) 213-88-53. Open daily from 10:00 a.m. to 7:00 p.m. Admission: $2.

The average dream
This isn't your

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average dream.

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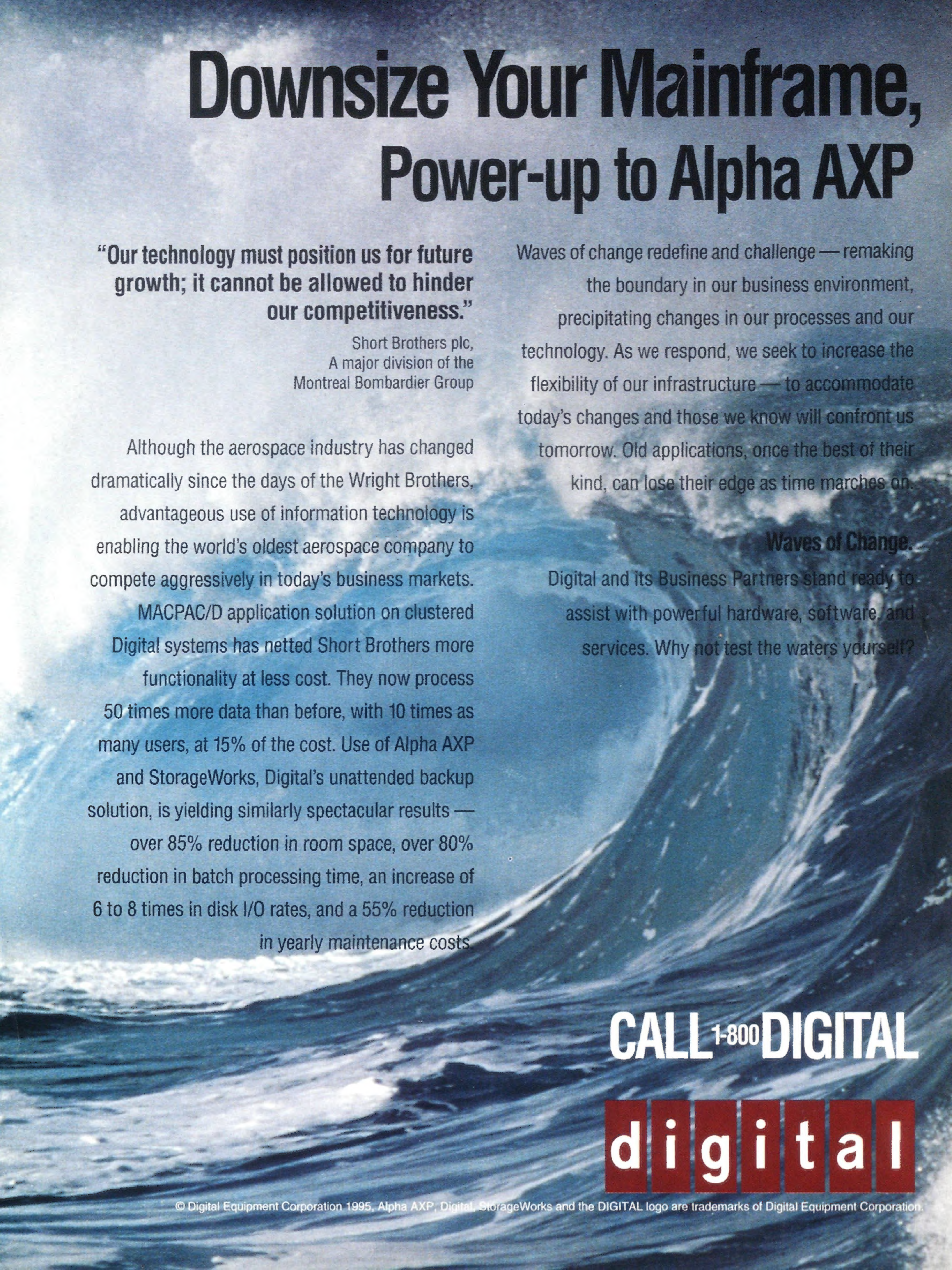

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